Ethyl Corporation HiTEC 3000 Fleet Testing Program

Violation Mileage Test
75,000 Mile Analysis
(based on quadratic regression)
Data Set ETHYL4S2
Pollutant Carbon Monoxide

Model	Violation Mileage(a) (miles) EEE	HT3	Sign ('+'= adverse HT3 effect)
D	21,709	21,840	-
E	13,056	5,936	+
F	99,000	99,000	0
T	20,046	17,316	+
C	99,000	99,000	0
G	99,000	99,000	0
H	24,204	29,474	-
I	99,000	99,000	0

EPA Sign Test: Observation of 2 '+' sign(s) in 4 trial(s) rejects the hypothesis of no adverse HiTEC 3000 effect at the 68.75 percent significance level(b). (For the purpose of the sign test, only observations with sign = + or - are counted as trials.)

Notes:
a. The violation mileage is the mileage (fitted by the quadratic regression curve) at which the standard is reached. Violation mileage = 0 if the zero mile emissions exceed the standard. Violation mileage = 99,000 if the regression curve lies entirely below the standard between 0 and 75,000 miles.
b. The lower the significance level, the greater the evidence of an adverse HiTEC 3000 effect.

Systems Applications Inc.
March 23, 1990

Ethyl Corporation HiTEC 3000 Fleet Testing Program

Maximum Percentage of Vehicles Failing Standard Test
75,000 Mile Analysis
(based on quadratic regression)
Data Set ETHYL4S2
Pollutant Hydrocarbons

Model	Maximum Estimated Percentage Failures (mileage)(a) EEE	HT3	Sign ('+'= adverse HT3 effect)
D	99.99 (69,379)	99.99 (53,595)	0
E	0.04 (75,000)	0.01 (75,000)	-
F	99.96 (49,404)	99.97 (54,431)	+
T	55.57 (75,000)	64.09 (53,612)	+
C	0.00 (60,309)	0.00 (49,479)	0
G	0.00 (75,000)	0.00 (57,308)	0
H	53.72 (75,000)	83.81 (75,000)	+
I	0.00 (75,000)	0.00 (75,000)	0

EPA Sign Test: Observation of 3 '+' sign(s) in 4 trials rejects the hypothesis of no adverse HiTEC 3000 effect at the 31.25 percent significance level(b). (For the purpose of the sign test, only observations with sign = + or - are counted as trials.)

Notes:
a. For each mileage the percentage of vehicles failing the standard is estimated using the quadratic regression curve. The first figure is the maximum percentage over all mileages from 0 to 75,000 miles. The figure in parentheses is the mileage at which the maximum occurs.
b. The lower the significance level, the greater the evidence of an adverse HiTEC 3000 effect.

Systems Applications Inc.
March 26, 1990

Ethyl Corporation HiTEC 3000 Fleet Testing Program

Maximum Percentage of Vehicles Failing Standard Test
75,000 Mile Analysis
(based on quadratic regression)
Data Set ETHYL4S2
Pollutant Nitrogen Oxides

Model	Maximum Estimated Percentage Failures (mileage)(a) EEE	HT3	Sign ('+'= adverse HT3 effect)
D	0.00 (75,000)	0.00 (0)	0
E	0.00 (75,000)	0.00 (64,365)	0
F	99.98 (75,000)	41.11 (75,000)	-
T	32.34 (75,000)	2.85 (75,000)	-
C	0.01 (75,000)	0.00 (75,000)	-
G	0.00 (61,634)	0.00 (54,158)	0
H	0.00 (66,770)	0.00 (2,599)	0
I	0.00 (75,000)	0.00 (53,361)	0

EPA Sign Test: Observation of 0 '+' sign(s) in 3 trials rejects the hypothesis of no adverse HiTEC 3000 effect at the 100.00 percent significance level(b). (For the purpose of the sign test, only observations with sign = + or - are counted as trials.)

Notes:
a. For each mileage the percentage of vehicles failing the standard is estimated using the quadratic regression curve. The first figure is the maximum percentage over all mileages from 0 to 75,000 miles. The figure in parentheses is the mileage at which the maximum occurs.
b. The lower the significance level, the greater the evidence of an adverse HiTEC 3000 effect.

Systems Applications Inc.
March 26, 1990

Ethyl Corporation HiTEC 3000 Fleet Testing Program

Maximum Percentage of Vehicles Failing Standard Test
75,000 Mile Analysis
(based on quadratic regression)
Data Set ETHYL4S2
Pollutant Carbon Monoxide

Model	Maximum Estimated Percentage Failures (mileage)(a)		Sign ('+'= adverse HT3 effect)
	EEE	HT3	
D	99.98 (75,000)	99.77 (70,507)	-
E	100.00 (75,000)	99.88 (61,672)	-
F	9.28 (75,000)	0.00 (75,000)	-
T	99.97 (75,000)	99.03 (71,411)	-
C	15.27 (49,354)	27.83 (49,603)	+
G	0.09 (56,940)	0.40 (65,372)	+
H	98.88 (59,770)	97.46 (65,448)	-
I	7.24 (75,000)	1.41 (55,896)	-

EPA Sign Test: Observation of 2 '+' sign(s) in 8 trials rejects the hypothesis of no adverse HiTEC 3000 effect at the 96.48 percent significance level(b). (For the purpose of the sign test, only observations with sign = + or - are counted as trials.)

Notes:

a. For each mileage the percentage of vehicles failing the standard is estimated using the quadratic regression curve. The first figure is the maximum percentage over all mileages from 0 to 75,000 miles. The figure in parentheses is the mileage at which the maximum occurs.
b. The lower the significance level, the greater the evidence of an adverse HiTEC 3000 effect.

Systems Applications Inc.
March 26, 1990

Ethyl Corporation HiTEC 3000 Fleet Testing Program

Cause or Contribute Test
75,000 Mile Analysis
(based on quadratic regression)
Data Set ETHYL4S2
Pollutant Hydrocarbons

Model	First Mileage at which Failure to Meet Standards Is Caused (. = not caused)(a)	Percent Failures EEE	Percent Failures HT3	Sign ('+'= adverse HT3 effect)
D	6,000	6.97	12.72	+
E	.	.	.	-
F	10,000	7.85	10.36	+
T	24,000	0.71	10.37	+
C	.	.	.	-
G	.	.	.	-
H	42,000	7.31	10.05	+
I	.	.	.	-

EPA Sign Test: Observation of 4 '+' sign(s) in 8 trials rejects the hypothesis of no adverse HiTEC 3000 effect at the 63.67 percent significance level(b). (For the purpose of the sign test, only observations with sign = + or - are counted as trials).

Notes:
a. If a number appears in this column then at this mileage, the percentage failures due to HiTEC 3000 estimated from the quadratic regression curve exceeds both ten percent and the estimated percentage failures due to EEE. The number that appears is the first mileage for which these conditions occur. A period appears if these conditions do not occur for any mileage up to 75,000 miles.
b. The lower the significance level, the greater the evidence of an adverse HiTEC 3000 effect.

Systems Applications Inc.
March 27, 1990

Ethyl Corporation HiTEC 3000 Fleet Testing Program

Cause or Contribute Test
75,000 Mile Analysis
(based on quadratic regression)
Data Set ETHYL4S2
Pollutant Nitrogen Oxides

Model	First Mileage at which Failure to Meet Standards Is Caused (. = not caused)(a)	Percent Failures EEE	Percent Failures HT3	Sign ('+'= adverse HT3 effect)
D	.	.	.	-
E	.	.	.	-
F	.	.	.	-
T	.	.	.	-
C	.	.	.	-
G	.	.	.	-
H	.	.	.	-
I	.	.	.	-

EPA Sign Test: Observation of 0 '+' sign(s) in 8 trials rejects the hypothesis of no adverse HiTEC 3000 effect at the 100.00 percent significance level(b). (For the purpose of the sign test, only observations with sign = + or - are counted as trials).

Notes:
a. If a number appears in this column then at this mileage, the percentage failures due to HiTEC 3000 estimated from the quadratic regression curve exceeds both ten percent and the estimated percentage failures due to EEE. The number that appears is the first mileage for which these conditions occur. A period appears if these conditions do not occur for any mileage up to 75,000 miles.
b. The lower the significance level, the greater the evidence of an adverse HiTEC 3000 effect.

Systems Applications Inc.
March 27, 1990

Ethyl Corporation HiTEC 3000 Fleet Testing Program

Cause or Contribute Test
75,000 Mile Analysis
(based on quadratic regression)
Data Set ETHYL4S2
Pollutant Carbon Monoxide

Model	First Mileage at which Failure to Meet Standards Is Caused (. = not caused)(a)	Percent Failures EEE	Percent Failures HT3	Sign ('+'= adverse HT3 effect)
D	12,000	8.42	10.38	+
E	0	6.17	24.74	+
F	.	.	.	-
T	5,000	7.02	11.78	+
C	25,000	5.31	10.62	+
G	.	.	.	-
H	.	.	.	-
I	.	.	.	-

EPA Sign Test: Observation of 4 '+' sign(s) in 8 trials rejects the hypothesis of no adverse HiTEC 3000 effect at the 63.67 percent significance level(b). (For the purpose of the sign test, only observations with sign = + or - are counted as trials).

Notes:
a. If a number appears in this column then at this mileage, the percentage failures due to HiTEC 3000 estimated from the quadratic regression curve exceeds both ten percent and the estimated percentage failures due to EEE. The number that appears is the first mileage for which these conditions occur. A period appears if these conditions do not occur for any mileage up to 75,000 miles.
b. The lower the significance level, the greater the evidence of an adverse HiTEC 3000 effect.

Systems Applications Inc.
March 27, 1990

Attachment F

STATISTICAL COMPARISON OF ECS AND ATL EMISSIONS TESTS AT 1000 MILES

When all 24 vehicles in model groups C, G, H, and I had accumulated 1000 miles (on clear fuel) at the ECS laboratory in Detroit, the cars were tested and then transported to the ATL laboratory in South Bend where further tests were done immediately upon arrival. The ATL procedure for simultaneously measuring tailpipe and engine-out emissions was considered questionable as it was suspected to result in a bias in the tailpipe emission rates. We therefore carried out tests to determine if there are any statistically significant differences between the 1000 mile tests performed at ECS and ATL. It should be noted that the statistical tests do not allow us to determine whether a difference, if observed, is due to a laboratory difference, the effect of transportation, or the effect of simultaneous testing of engine-out and tailpipe emissions. Nevertheless, the results show statistically significant differences, which justifies the exclusion of the 1000 mile ATL emisions tests from the main working data set.

The tests described below were carried out on the data set consisting of the first two ECS tests for each vehicle and the first two ATL tests for each vehicle.

HOMOGENEITY OF VARIANCE TESTS

First we tested whether there was a significant difference in variability between the ECS and ATL emissions tests. For each model and pollutant we used all the data to compute pooled estimates of the two variances for the tests performed at each laboratory. Using an F test the true variances are regarded as different if the ratio of the estimates is either too small or too large. This analysis uses the reasonable assumptions that all the observations are (approximately) independent and that each set of laboratory tests has the same variance. These assumptions are needed separately for each model and pollutant combination.

The results are summarized in Table F-1. The statistically significant results have been marked with an asterisk. In those cases such a small or large observed ratio would occur less than 5 percent of the time if the true variances are the same. Only the cases of models C and G for CO and model I for NO_x show significant differences in variability. Moreover, there appears to be no clear pattern in the significant results: there is no model for which the variances are significantly different for each pollutant, and there is no pollutant for which the variances are significantly different for each model. One might therefore conclude that there is only a small overall difference in variability.

SIGN OF DIFFERENCE TESTS

As a simple test to see if the 1000-mile mean emissions were different between the two laboratories we carried out the following sign test. For each model and pollutant combination we counted the number of occasions where the mean emissions for a vehicle was greater at ECS than at ATL. Since six cars were tested for each model there is evidence of a difference if this number is either close to zero or close to six. In each case we computed a p-value which gives the probability of observing such an extreme result (in either direction) assuming no true difference. Note that this test considers only the sign of the difference and not the magnitude; thus large differences in means are counted as much as very small differences.

The results appear in Table F-2. Significant results (where the p-value is less than 5 percent) are marked with an asterisk. Greater concentrations at ATL are detected for NO_x for models C, G, and I, for all three pollutants for model C, and for CO for model I. Since there are several significant results this simple and not very powerful test shows that overall there are differences in the means.

Attachment F

STATISTICAL COMPARISON OF ECS AND ATL EMISSIONS TESTS AT 1000 MILES

TABLE F-1. Difference in variances between ECS and ATL tests at 1000 miles.

Model	Pollutant	Estimated Variance ECS	Estimated Variance ATL	Ratio of Variances
C	HC	0.0001	0.0004	0.195
	NO_x	0.0002	0.0005	0.342
	CO	0.0118	0.0836	0.141*
G	HC	0.0002	0.0002	0.954
	NO_x	0.0001	0.0001	0.992
	CO	0.0006	0.0206	0.029*
H	HC	0.0001	0.0002	0.548
	NO_x	0.0018	0.0010	1.923
	CO	0.0099	0.0453	0.218
I	HC	0.0002	0.0002	0.049
	NO_x	0.0001	0.0012	0.049*
	CO	0.0319	0.0447	0.713

* Significant at the 5 percent level

TABLE F-2. Sign test for difference in mean emission rates between ECS and ATL tests at 1000 miles.

Model	Pollutant	No. of Cars Where the Mean Increased (maximum 6)	Significance Level (%)
C	HC	6	3.1*
	NO_x	6	3.1*
	CO	6	3.1*
G	HC	2	68.7
	NO_x	6	3.1*
	CO	5	21.9
H	HC	1	21.9
	NO_x	5	21.9
	CO	5	21.9
I	HC	1	21.9
	NO_x	6	3.1*
	CO	6	3.1*

* Significant at the 5 percent level.

DIFFERENCE IN MEANS TEST

A more powerful test to determine if the means are different can be made under the assumptions that all the observations are independent and have the same variance (within each model and pollutant combination). The reasonableness of the equal variance assumption is discussed above. For each model/pollutant combination we used a general linear model to test for a difference in means and for a difference in interaction. The difference in means test determines whether the mean of the six true car-means is the same at ECS and ATL. The interaction test determines if the laboratory differences in the true mean are the same for every vehicle.

The results are given in Table F-3. Statistically significant results (at the 5 percent level) are marked with an asterisk. For every model the mean emissions for CO and NO_x increased at ATL, and the increase was statistically significant. The increases ranged from 0.10 to 0.79 g/mi for CO and from 0.02 to 0.08 g/mi for NO_x. There was no consistent effect on the HC emissions, although there were decreases for three out of the four models (G, H, and I). In all but one case the interactions were not statistically significant, which means that the change in the means did not vary significantly by vehicle. Thus, the overall conclusion is that there are statistically and practically significant increases in the mean emission rates at ATL for the pollutants CO and NO_x.

COMPARISON OF SIGN OF DIFFERENCE TESTS AND DIFFERENCE IN MEANS TEST

The difference in means test is better than the sign of difference test because it has greater power. This means that although both tests have the same probability of erroneously detecting a difference when there is no real difference, the difference in means test is more likely to correctly detect a real difference. The reason is that the sign of difference test ignores the magnitude of the difference. On the other hand, the Sign of Difference test requires fewer assumptions about the behavior of the measurement process. Nevertheless, the sign of difference test detected most of the changes in the means that the difference in means test detected.

TABLE F-3. Differences in means between ECS and ATL tests at 1000 miles.

Model	Pollutant	Mean of Car-Means ECS	Mean of Car-Means ATL	Difference in Means†	Significance Level for Testing Change in the Mean (%)	Significance Level for Testing Interaction (%)
C	HC	0.126	0.141	0.015	0.01*	95.23
	NO_x	0.096	0.174	0.078	0.01*	6.84
	CO	1.310	2.104	0.794	0.01*	37.76
G	HC	0.101	0.093	-0.008	20.52	66.94
	NO_x	0.158	0.180	0.022	0.06*	39.33
	CO	0.774	0.872	0.099	3.70*	70.68
H	HC	0.175	0.161	-0.014	1.53*	52.27
	NO_x	0.371	0.433	0.062	0.15*	20.54
	CO	1.364	1.591	0.227	0.58*	37.77
I	HC	0.167	0.157	-0.010	10.17	88.66
	NO_x	0.227	0.290	0.063	0.01*	1.80*
	CO	1.577	2.011	0.434	0.02*	49.22

* Significant at the 5 percent level.

† This column shows the difference between the mean emissions (mean of the car-means) at ECS and the mean emissions at ATL. A positive value measures how much higher the mean emissions are at ATL compared to ECS. A negative value measures how much lower the mean emissions are at ATL compared to ECS.

CONCLUSION

We conclude from this analysis that there is no significant change in variability between the ECS and ATL tests but there are significant increases in the mean concentrations for CO and NO_X at ATL, which are likely attributable to the procedure used to simultaneously estimate tailpipe emissions and engine-out emissions. Therefore, the 1000 mile ATL tests should not be included in the data analysis.

Attachment G

STATISTICAL ANALYSIS OF EMISSIONS BEFORE AND AFTER 50,000 MILE COMPONENT CHANGES

Attachment G

STATISTICAL ANALYSIS OF EMISSIONS BEFORE AND AFTER 50,000 MILE COMPONENT CHANGES

In this attachment we describe our results comparing tailpipe emissions before and after the 50,000 mile component changes. The results show no overall short-term reduction or increase in emissions. However, there were large decreases for the model D emissions for both HC and CO on both fuels, and small but statistically significant increases for models G and H for both HC and CO, on HiTEC 3000 only. Except for these cases, the effects of component changes on the EEE and HiTEC 3000 vehicles were not noticeably different. However the effects on model H are important due to the high fraction of 1988 sales for this model and its consequent weight in the statistical analyses. Therefore we describe two alternative procedures to adjust for these component changes; these alternative procedures were employed to create data sets ETHYL4S2 and ETHYL4S3.

At 50,000 miles the emission control systems in all vehicles in the fleet were carefully inspected; the emission control system components were changed in some vehicles. In nearly every case the same components were changed for every vehicle of the same model. Table G-1 details the component changes made, in serial order, and average test mileages before and after the component changes. In this analysis and for all the results reported in this attachment, only the first two emissions tests before and after the component changes were used; unscheduled maintenance tests were excluded. Note that no component changes were made for models C and G. For those models, therefore, the present analysis measures only the effect of the increase in mileage from 50,000 miles to 51,000 miles and not the effect of component changes. Note also that in most cases the component replacement was permanent; exceptions are indicated in the footnotes. The other noticeable feature of Table G-1 is that the large number of component checks on vehicle D5 resulted in a

TABLE G-1. Component changes at 50,000 mile testing interval and mean test mileages.

Model	Vehicle Number	Mean test mileage before component changes	Mean test mileage after component changes	Difference in mileages	Component changes
D	D1	49931.5	50136.5	205.0	Fuel injectors, fuel pump, air sensor
	D2	50099.5	50304.0	204.5	Fuel injectors, fuel pump, air sensor
	D4	50014.0	50139.5	125.5	Fuel injectors, fuel pump, air sensor
	D5	49914.0	50374.0	460.0	Fuel injectors, fuel pump, air sensor
	D6	49957.0	50114.5	157.5	Fuel injectors, fuel pump, air sensor
E	E1	49983.0	50094.5	111.5	Fuel injectors, map sensor
	E2	49989.5	50155.5	166.0	Fuel injectors, map sensor
	E3	50000.0	50106.0	106.0	Fuel injectors, map sensor
	E4	50094.5	50217.0	122.5	Fuel injectors, map sensor
	E5	49832.5	49943.5	111.0	Fuel injectors, map sensor
	E6	50016.5	50148.5	132.0	Fuel injectors, map sensor
F	F1	49915.5	50112.5	197.0	Fuel injectors
	F2	50014.5	50157.0	142.5	Fuel injectors
	F3	49987.5	50127.0	139.5	Temporary slave canister,* fuel injectors
	F4	50099.0	50225.0	126.0	Fuel injectors
	F5	49980.0	50088.0	108.0	Fuel injectors
	F6	50014.5	50140.5	126.0	Fuel injectors

* After testing with a new slave canister, the original slave canister was replaced in the vehicle.

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TABLE G-1. (continued).

Model	Vehicle Number	Mean test mileage before component changes	Mean test mileage after component changes	Difference in mileages	Component changes
T	T1	50051.0	50210.0	159.0	Fuel injectors
	T2	50018.5	50177.0	158.5	Fuel injectors
	T3	50010.5	50170.0	159.5	Fuel injectors
	T4	49961.0	50097.0	136.0	Fuel injectors
	T5	50038.0	50175.0	137.0	Fuel injectors
	T6	50080.0	50216.0	136.0	Fuel injectors
C	C1	50022.5	51247.0	1224.5	
	C2	50021.5	51187.0	1165.5	
	C3	50024.0	51214.5	1190.5	
	C4	50021.0	51197.5	1176.5	
	C5	50023.5	51210.0	1186.5	
	C6	50023.0	51219.0	1196.0	
G	G1	50024.0	51059.5	1035.5	
	G2	50022.5	51084.0	1061.5	
	G3	50024.0	51061.5	1037.5	
	G4	50023.5	51061.5	1038.0	
	G5	50048.0	51088.0	1040.0	
	G6	50050.0	51079.0	1029.0	

TABLE G-1. (concluded).

Model	Vehicle Number	Mean test mileage before component changes	Mean test mileage after component changes	Difference in mileages	Component changes
H	H1	50020.0	50376.0	356.0	Transmission service, ignition service, fuel injectors
	H2	50038.5	50447.0	408.5	Transmission service, fuel injectors
	H3	50060.0	50417.5	357.5	Transmission service, fuel injectors
	H4	50037.0	50432.0	395.0	Transmission service, fuel injectors
	H5	50112.5	50532.0	419.5	Transmission service, fuel injectors
	H6	50081.0	50549.0	468.0	Transmission service, fuel injectors
I	I1	50057.0	50338.5	281.5	Fuel injectors
	I2	50025.0	50239.0	214.0	Fuel injectors
	I3	50054.5	50283.0	228.5	Fuel injectors
	I4	50163.5	50384.5	221.0	Fuel injectors
	I5	50063.0	50342.0	279.0	Fuel injectors
	I6	50033.5	50284.5	251.0	FUel injectors

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relatively large difference in accumulated mileage from start to completion of the component testing.

For each vehicle, we calculated the average emissions before and after the component changes for each pollutant; these averages are displayed by model group in Figures G-1, G-2, and G-3 for hydrocarbons, nitrogen oxides, and carbon monoxide, respectively.

The figures show that the emissions increase and decrease about as often (which is what one would expect if there were no emissions effect of the component changes), with the notable exception of model D. All average pollutant emissions decrease for model D except for NO_X emissions on EEE cars. In general, any effects are consistent across cars for each model and pollutant. The main exception is for vehicle D5 (on HiTEC 3000) where the HC decrease of 0.3725 g/mi is noticeably larger than the decreases for the other model D vehicles. However, the CO and NO_X emissions were similar across all the model D vehicles. Other notable inconsistencies are the relatively large CO increase of 1.4205 g/mi for G3 (on HiTEC 3000), a relatively large NO_X decrease of 0.2425 g/mi for F4 (on EEE), and a relatively large NO_X increase of 0.1270 g/mi for I3 (on EEE).

The detailed results of the statistical analysis of emissions before and after the component changes are displayed in Tables G-2, G-3, and G-4. These tables give, for each model and fuel combination, averages for each pollutant calculated from only the first two tests before the component changes and the first two tests after the component changes. The first three columns in each table contain the mean of the car-means for the three HiTEC 3000 vehicles before the component changes, the mean of the vehicle-means for the same three vehicles after the component changes, and the difference in the means, respectively. A positive value in the third column occurs if the emissions increase after the component changes; conversely, a negative value indicates an average decrease after component changes. Statistically significant differences (based on two-sided five percent tests) are underlined. Similar results for the EEE vehicles appear in the fourth to sixth columns. The last column compares the component change effects for HiTEC 3000 and EEE vehicles, and is the difference between the third and sixth columns. The last column is therefore positive if the increase is greater (or the decrease is less) for the HiTEC 3000 vehicles.

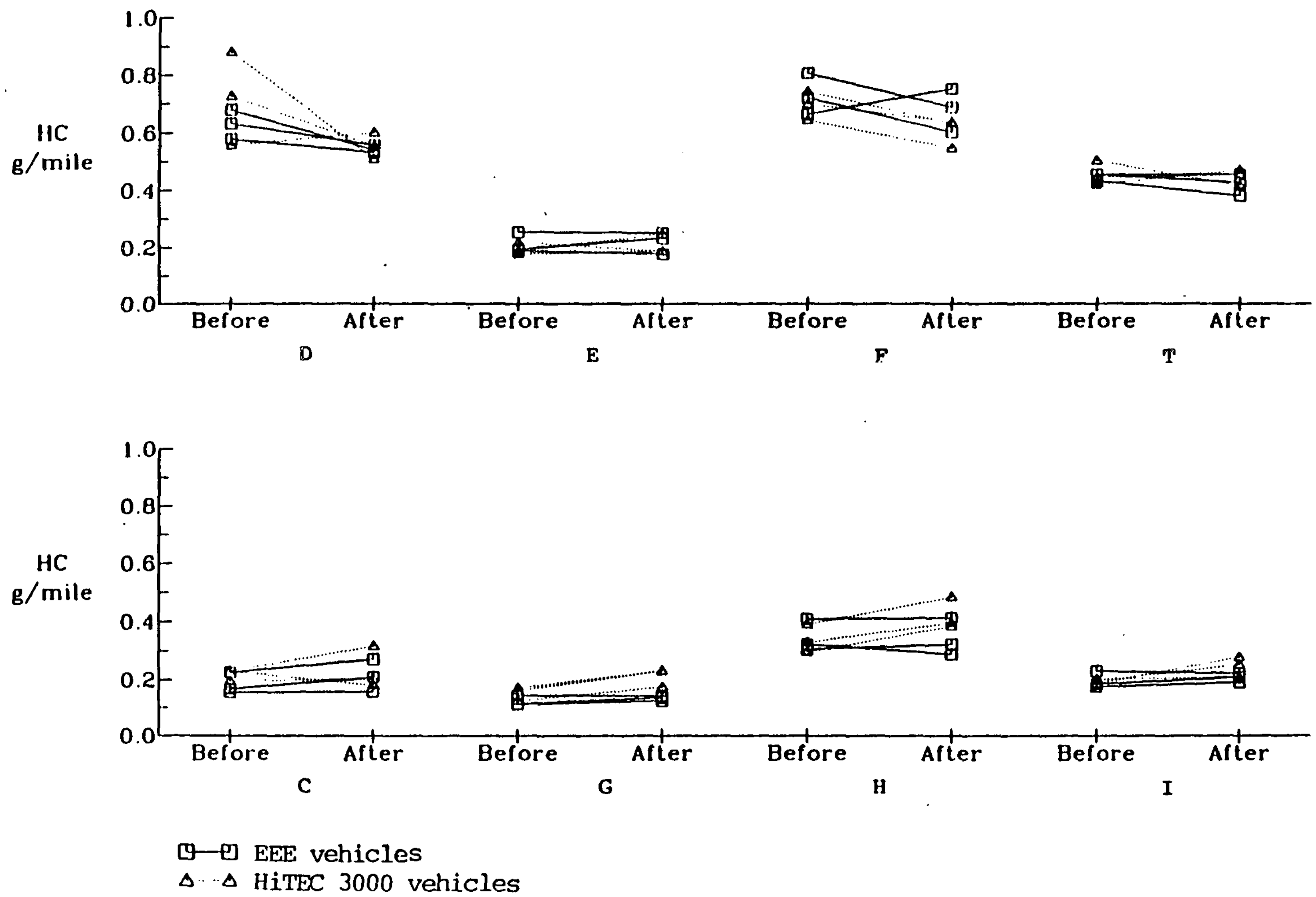

FIGURE G-1. Average hydrocarbon emissions before and after 50,000 mile component changes. Data set ETHYL4S.

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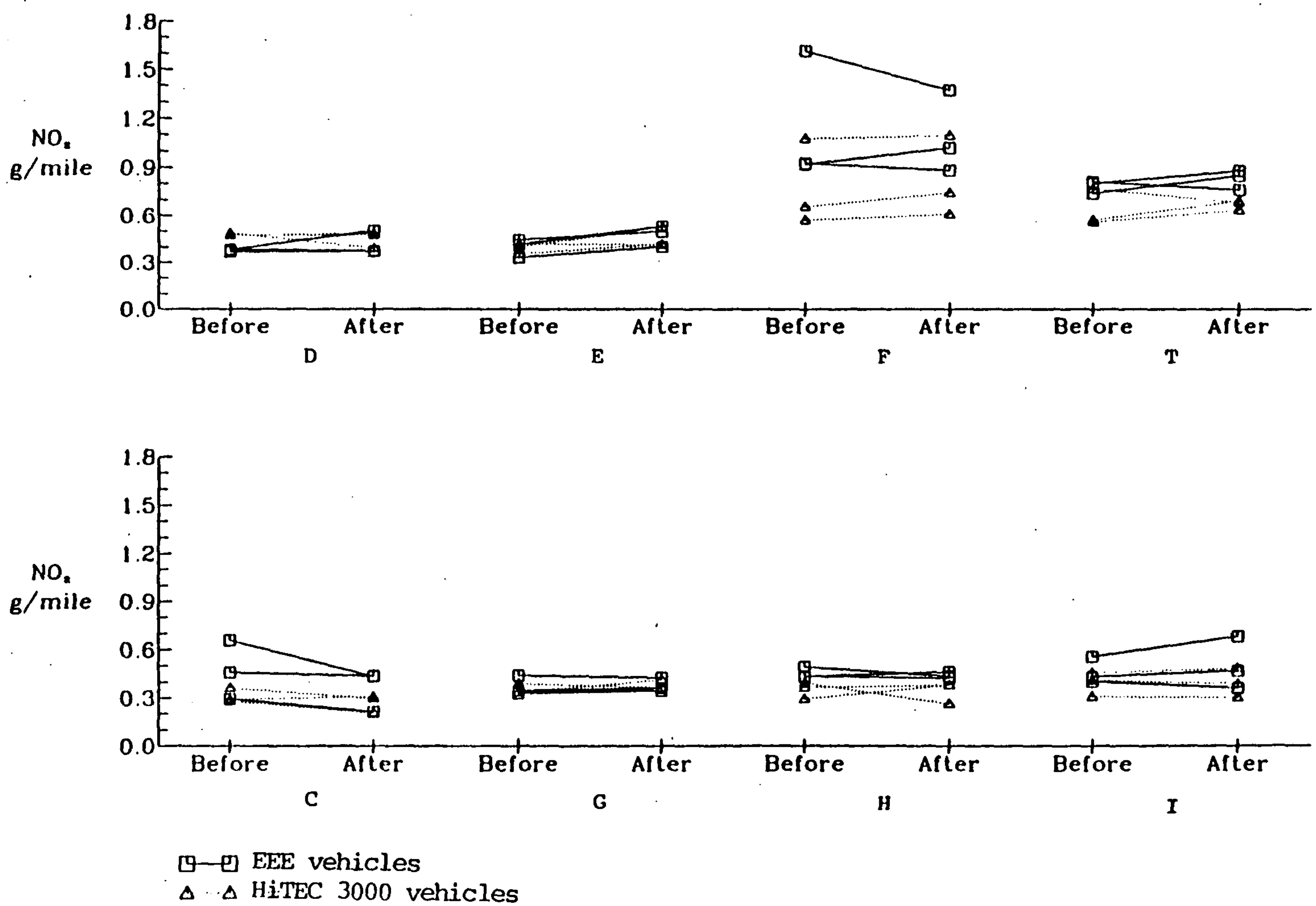

FIGURE G-2. Average nitrogen oxide emissions before and after 50,000 mile component changes. Data set ETHYL4S.

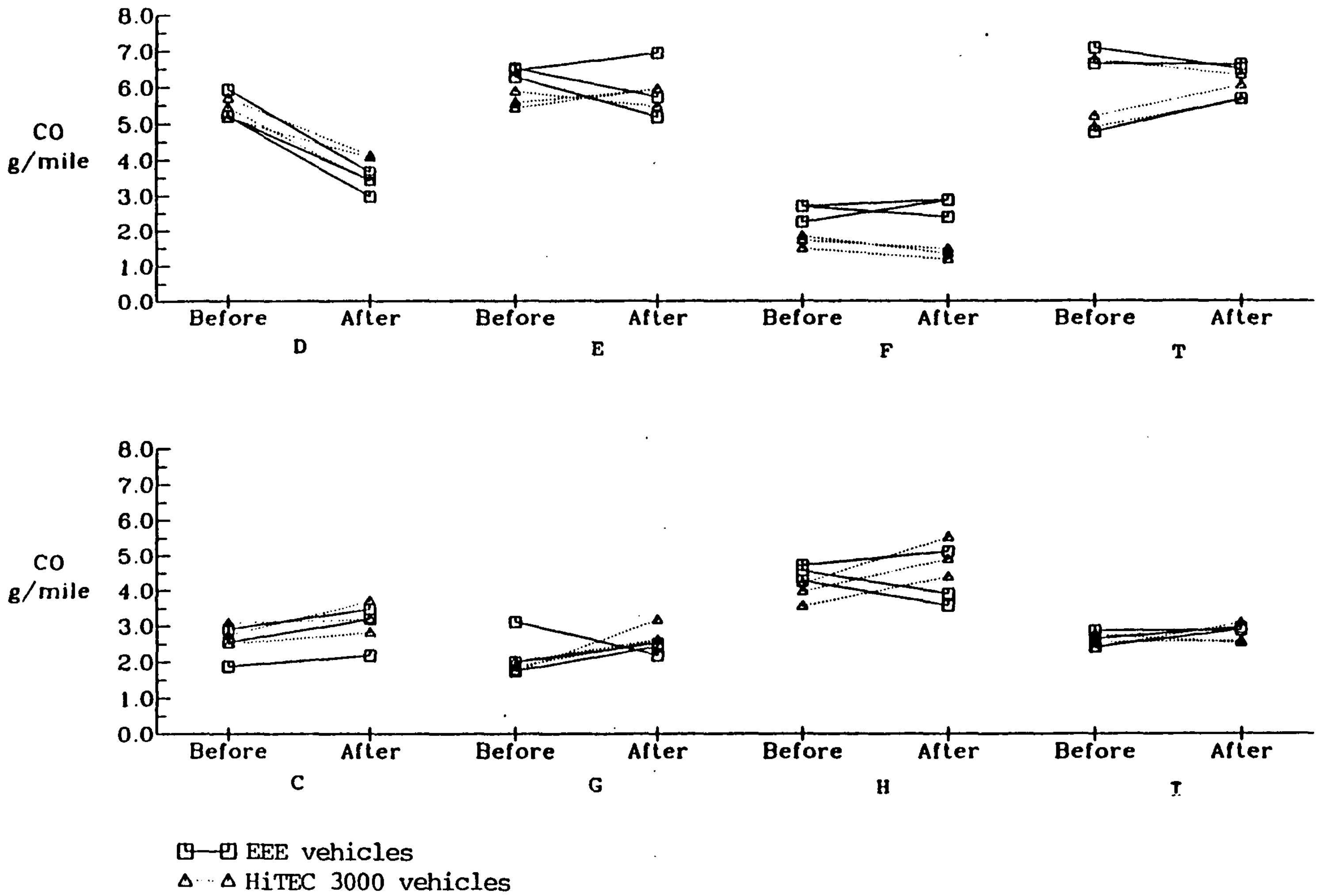

FIGURE G-3. Average carbon monoxide emissions before and after 50,000 mile component changes. Data set ETHYL4S.

TABLE G-2. Changes in hydrocarbon emissions before and after 50,000 mile component changes.

HC	(1) Mean before component changes for HT3 (g/mi)	(2) Mean after component changes for HT3 (g/mi)	(3) After component changes increase for HT3 (g/mi)* (2) - (1)	(4) Mean before component changes for EEE (g/mi)	(5) Mean after component changes for EEE (g/mi)	(6) After component changes increase for EEE (g/mi)* (5) - (4)	(7) Differences in increase (g/mi)** (3) - (6)
D	0.7207	0.5545	<u>-0.1662</u>	0.6052	0.5445	-0.0607	<u>-0.1054</u>
E	0.1943	0.2065	0.0122	0.2122	0.2190	0.0068	0.0053
F	0.6925	0.6033	<u>-0.0892</u>	0.7285	0.6785	-0.0500	-0.0392
T	0.4542	0.4448	-0.0093	0.4458	0.4192	-0.0267	0.0173
C	0.2200	0.2340	0.0140	0.1828	0.2127	0.0298	-0.0158
G	0.1528	0.2120	<u>0.0592</u>	0.1230	0.1333	0.0103	<u>0.0488</u>
H	0.3368	0.4193	<u>0.0825</u>	0.3445	0.3385	-0.0060	<u>0.0885</u>
I	0.1940	0.2438	0.0498	0.1947	0.2045	0.0098	0.0400

* Each value is the mean of the car-means after the component changes minus the mean of the car-means before the component changes. Significant differences are underlined. The figures may not agree in the last decimal place due to rounding.

** Each value is the difference between columns (3) and (6). The figures may not agree in the last decimal place due to rounding. A positive value occurs if the mean emissions increase more with the HiTEC 3000 fuel (after the component changes) than they increase with the clear fuel. Significant differences are underlined.

TABLE G-3. Changes in NO_x emissions before and after 50,000 mile component changes.

NOx	(1) Mean before component changes for HT3 (g/mi)	(2) Mean after component changes for HT3 (g/mi)	(3) After component changes increase for HT3 (g/mi)* (2) - (1)	(4) Mean before component changes for EEE (g/mi)	(5) Mean after component changes for EEE (g/mi)	(6) After component changes increase for EEE (g/mi)* (5) - (4)	(7) Differences in increase (g/mi)** (3) - (6)
D	0.4805	0.4520	-0.0285	0.3775	0.4395	0.0620	-0.0905
E	0.3922	0.4537	0.0615	0.3987	0.4778	0.0792	-0.0177
F	0.7663	0.8128	0.0465	1.1513	1.0878	-0.0635	0.1100
T	0.6292	0.6655	0.0363	0.7787	0.8242	0.0455	-0.0092
C	0.3107	0.2715	-0.0392	0.4697	0.3622	-0.1075	0.0683
G	0.3537	0.3800	0.0263	0.3727	0.3792	0.0065	0.0198
H	0.3510	0.3423	-0.0087	0.4530	0.4407	-0.0123	0.0037
I	0.3912	0.3917	0.0005	0.4630	0.5040	0.0410	-0.0405

* Each value is the mean of the car-means after the component changes minus the mean of the car-means before the component changes. Significant differences are underlined. The figures may not agree in the last decimal place due to rounding.

** Each value is the difference between columns (3) and (6). The figures may not agree in the last decimal place due to rounding. A positive value occurs if the mean emissions increase more with the HiTEC 3000 fuel (after the component changes) than they increase with the clear fuel. Significant differences are underlined.

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TABLE G-4. Changes in CO emissions before and after 50,000 mile component changes.

CO	(1) Mean before component changes for HT3 (g/mi)	(2) Mean after component changes for HT3 (g/mi)	(3) After component changes increase for HT3 (g/mi)* (2) - (1)	(4) Mean before component changes for EEE (g/mi)	(5) Mean after component changes for EEE (g/mi)	(6) After component changes increase for EEE (g/mi)* (5) - (4)	(7) Differences in increase (g/mi)** (3) - (6)
D	5.4255	3.8583	-1.5672	5.2067	3.2065	-2.0002	0.4331
E	5.6253	5.7788	0.1535	6.4207	5.9468	-0.4738	0.6273
F	1.6818	1.3318	-0.3500	2.5433	2.7092	0.1658	-0.5158
T	5.6090	5.9857	0.3767	6.1572	6.2453	0.0882	0.2885
C	2.9028	3.2330	0.3302	2.4458	2.9420	0.4962	-0.1660
G	1.8725	2.7820	0.9095	2.2822	2.3635	0.0813	0.8282
H	3.9405	4.9193	0.9788	4.5072	4.1865	-0.3207	1.2995
I	2.5433	2.7102	0.1668	2.6305	2.8845	0.2540	-0.0872

* Each value is the mean of the car-means after the component changes minus the mean of the car-means before the component changes. Significant differences are underlined. The figures may not agree in the last decimal place due to rounding.

** Each value is the difference between columns (3) and (6). The figures may not agree in the last decimal place due to rounding. A positive value occurs if the mean emissions increase more with the HiTEC 3000 fuel (after the component changes) than they increase with the clear fuel. Significant differences are underlined.

90025 3

Statistically significant differences between HiTEC 3000 and EEE in the last column are underlined (based on two-sided five percent tests).

As shown in the figures, for each pollutant and fuel, the tabulated emissions increase for about half of the models. Statistically significant increases occur about as frequently as statistically significant decreases. One obvious feature is the very large and statistically significant decreases for model D on either fuel for CO and on HiTEC 3000 for HC. On the other hand, the increases in HC and CO emissions for models G and H are statistically significant, whereas the corresponding EEE effects are nonsignificant. These effects have a greater practical importance than the effects on model D, even though the model D effects are larger in magnitude, because of the high sales fraction corresponding to model H. Another notable feature is the unusually large difference between the mean effects on NO_x emissions for the two fuels on Model F (also notable in Figure G-2 is the large variation in the NO_x measurements). This observed result is primarily caused by the large decrease in NO_x emissions for the EEE vehicle F4.

The values in the seventh column compare the effects of the component changes on the two fuels. The most important pattern is the statistically significantly higher increases for HC and CO emissions on both models G and H for HiTEC 3000 compared to EEE. This pattern is a reflection of the statistically significant increases for HiTEC 3000 and nonsignificant effects for EEE for those models.

A possible explanation for some of the observed increases is that although the changes in the emission control system components might be expected to decrease emissions, these decreases are counteracted by the increases in emissions with increased mileage. As a test of this hypothesis, the above analysis was repeated after adjusting for the mileage effect. A straight line (regression line) was fitted to all the data from 30,000 miles to the two tests before the component changes at 50,000 miles for each pollutant, fuel and model combination. The slope of this line multiplied by the mileage increase (shown in Table G-1) estimates the increase or decrease in emissions due to the increased mileage between the two sets of emissions tests. This was subtracted from the observed differences to estimate the effect of the component changes alone. The results of this adjusted analysis differ only slightly from the results in Tables G-2, G-3, and G-4 (in most cases only in the third or fourth decimal place) and so are not reported. Thus, we can conclude that the mileage effect is negligible compared to any effect of the component changes.

Due to the large component change effects demonstrated by this analysis, especially for HC and CO emissions for the HiTEC 3000-fueled vehicles of Models D, G, and H, it is appropriate to adjust the data for these component change effects for the 75,000 mile data analysis. We have used two approaches for this adjustment. The first approach is based on the hypothesis that any effect of the component changes will tend to be of an instantaneous nature, due to the mileage accumulation required before the replaced component is functioning properly in the vehicle. On this basis, all the emissions tests at 50,000 miles after the component changes were excluded. The next set of emissions tests were carried out at the next mileage interval, 55,000 miles, and so were included. This is precisely the procedure that reduced data set ETHYL4S to data set ETHYL4S2; the latter data set was used for most of the statistical analyses of the 75,000 mile data.

An alternative approach is based on the hypothesis that the effect of the component changes is a permanent additive effect. Thus the increase (or decrease) is assumed to apply to all emissions test results after the component changes and the effect is the same at all future mileages. Under this approach, an appropriate method of adjusting for the component changes is to subtract the increase (or add back the decrease). This adjustment was computed as an average increase (or decrease) for each model/fuel/pollutant combination. For example, for hydrocarbon emissions on model D, the average HiTEC 3000 decrease of 0.1662 g/mi was added to every HC measurement after the component changes for the three HiTEC 3000 vehicles in that model group. Similarly, for model H, the average HiTEC 3000 increase of 0.0825 g/mi was subtracted from every HC measurement after the component changes for the three HiTEC 3000 vehicles in model group H. The average changes are given in columns 3 and 6 of Tables G-2, G-3, and G-4. This procedure was applied to data set ETHYL4S2 to create the component change adjusted data set ETHYL4S3.

Attachment H

STATISTICAL ANALYSIS OF ECS TESTER BIAS

Attachment H

STATISTICAL ANALYSIS OF ECS TESTER BIAS

In this attachment we discuss the issue of tester bias and resultant variability in the emissions test results for ECS vehicles. We develop a method of adjusting for this bias and reducing this source of variability. Our results show several statistically significant tester biases, but since the testers appear to have been approximately equally divided among the two fuel groups, the effect on the fuel comparisons is generally small.

Although tester 1 performed the majority of the emissions tests for the ECS laboratory up to 35,000 miles, later tests were mainly run by different testers when tester 1 became ill. Since tester 1 did perform the majority of the early tests, and is the most experienced of the testers at the ECS laboratory, we chose to use tester 1 as the reference tester. Thus our estimates of tester bias will measure the effect of a given tester compared to tester 1. Further, our adjustment of the emissions data is based on recomputing emissions as if all tests had been performed by tester 1.

A comparison of the frequencies of the testers assigned to vehicles shows that each tester was used approximately as often on EEE-fueled vehicles as on HiTEC 3000-fueled vehicles; the frequencies are given in Table H-1. For example the first three rows of column 1 show that tester 1 was used for 39 emissions tests for the EEE vehicles in model group D, for 52 tests for the HITEC 3000 vehicles in the same group, and for a total of 91 tests on model D. The last three rows give totals over all model groups. Note that there was no tester 6 in the Ethyl fleet testing program and that tester 7 was not used for any of the emission tests on model T.

The final column of Table H-1, labeled 'Significance level', reports the result of a chi-square test that determines if there is any tester who was used significantly

TABLE H-1. Frequency distribution (counts) of tester against model group and fuel. Data set ETHYL4S2.

Model	Fuel	1	2	3	4	5	7	Total	Significance Level[a] (%)
D	EEE	39	10	9	11	3	0	72	
	HT3	52	16	18	15	6	1	108	
	Total	91	26	27	26	9	1	180	86.0
E	EEE	50	13	23	18	3	1	108	
	HT3	58	13	18	18	0	1	108	
	Total	108	26	41	36	3	2	216	55.7
F	EEE	65	12	13	11	3	0	104	
	HT3	68	8	12	11	4	1	104	
	Total	133	20	25	25	7	1	208	84.3
T	EEE	65	9	18	18	4	0	114	
	HT3	69	9	18	16	2	0	114	
	Total	134	18	36	34	6	0	228	92.4
All[b]	EEE	219	44	63	58	13	1	398	
	HT3	247	46	66	60	12	3	434	
	Total	466	90	129	118	25	4	832	98.9

[a] The significance level reported is the result of a chi-square test that the tester proportions were the same for each fuel. Values higher than 5 percent correspond to no significant differences.

[b] Counts from all four ESC-tested models are summed.

more often for one of the fuels compared to the other fuel; for this test the low frequencies of testers 5 and 7 were combined. Since all of the reported significance levels are much larger than 5 percent, there is no statistical evidence of a difference in tester allocation between clear-fuel and HiTEC 3000 vehicles. Consequently, one can expect that tester differences will only have a small effect on the fuel effect comparisons.

Our procedure for estimating tester bias for the four ECS models (D, E, F, and T) is essentially based on the average difference between the emissions for tests performed by a given tester, and the emissions for tests performed by tester 1, when those tests were performed at the same mileage interval on the same vehicle. This average difference estimates the additive effect of that tester compared with tester 1. However the procedure used also takes into account different comparisons at different mileage intervals. Suppose, for example, that testers 1 and 2 are both used at 30,000 miles for some vehicle and that testers 2 and 4 are both used at 60,000 miles for a vehicle in the same model group (possibly the same vehicle). The difference at 30,000 miles is incorporated into the effect of tester 2. On the other hand, the effect of tester 4 compared to tester 1 incorporates both comparisons by subtracting the difference between testers 2 and 4 at 60,000 miles from the difference between testers 2 and 1 at 30,000 miles.

More specifically, we use the following method. We make the reasonable assumption that the tester effect is additive. Thus we assume that the increase or decrease in the emission rate compared to the true mean would be the same if the tester were changed from the actual tester to another given tester regardless of the vehicle, fuel and mileage. Specific effects will be estimated for each combination of pollutant, model, and tester. We also assume that the mean emissions can vary by model, vehicle, fuel, mileage interval, and pollutant, but the variance depends only on the pollutant. The unknown parameters in this linear model were estimated appropriately, using standard statistical software, together with estimates of the tester biases and their standard errors; the results are reported in Tables H-2, H-3, and H-4 for HC, CO, and NO_x, respectively. The main pattern is that for the various combinations of pollutant and model, tester 4 emissions are in most cases higher than tester 1, and tester 2 emissions are in most cases lower than tester 1 (except for CO and NO_x emissions on model D). Except for HC emissions on model F, the differ-

TABLE H-2

Tester Biases
75,000 Mile Analysis
Data Set: ETHYL4S2
Pollutant: HC

Model	Tester	Estimated Tester Bias (tester minus tester 1) (g/mi)	Standard Error (g/mi)	Significance Level (%)
D	2	-0.014	0.077	85.7
	3	-0.068	0.066	30.4
	4	0.130	0.033	0.0
	5	-0.011	0.040	78.4
	7	-0.165	0.101	10.6
E	2	-0.035	0.007	0.0
	3	0.039	0.017	0.4
	4	-0.011	0.015	44.8
	5	0.016	0.017	34.1
	7	-0.013	0.021	55.1
F	2	-0.009	0.026	73.7
	3	0.046	0.058	42.8
	4	0.020	0.021	33.6
	5	0.004	0.023	86.3
	7	-0.039	0.058	50.2
T	2	-0.008	0.014	59.5
	3*	0.000		
	4	0.075	0.013	0.0
	5*	0.047		

* See text for details on the estimation of tester biases for model T, testers 3 and 5.

TABLE H-3

Tester Biases
75,000 Mile Analysis
Data Set: ETHYL4S2
Pollutant: CO

Model	Tester	Estimated Tester Bias (tester minus tester 1) (g/mi)	Standard Error (g/mi)	Significance Level (%)
D	2	0.94	0.61	12.7
	3	0.12	0.53	81.4
	4	1.20	0.26	0.0
	5	-0.06	0.32	84.9
	7	1.40	0.81	8.6
E	2	-0.59	0.19	0.3
	3	0.63	0.44	15.7
	4	0.06	0.39	87.5
	5	1.08	0.44	1.7
	7	-0.03	0.54	95.8
F	2	-0.23	0.13	8.5
	3	0.34	0.30	25.3
	4	0.33	0.11	0.3
	5	-0.06	0.12	62.2
	7	-0.39	0.30	18.6
T	2	-0.40	0.32	21.4
	3*	0.00		
	4	2.36	0.28	0.0
	5*	3.04		

* See text for details on the estimation of tester biases for model T, testers 3 and 5.

TABLE H-4

Tester Biases
75,000 Mile Analysis
Data Set: ETHYL4S2
Pollutant: NO_x

Model	Tester	Estimated Tester Bias (tester minus tester 1) (g/mi)	Standard Error (g/mi)	Significance Level (%)
D	2	0.14	0.07	6.0
	3	0.05	0.06	42.4
	4	0.13	0.03	0.0
	5	0.04	0.04	29.9
	7	0.22	0.10	2.6
E	2	-0.03	0.02	8.9
	3	0.09	0.04	1.8
	4	0.04	0.03	23.2
	5	0.07	0.04	6.1
	7	0.04	0.05	39.4
F	2	-0.10	0.03	0.3
	3	0.11	0.07	13.7
	4	0.04	0.03	15.1
	5	-0.09	0.03	0.3
	7	0.01	0.07	94.5
T	2	-0.10	0.03	0.3
	3*	0.00		
	4	0.13	0.03	0.0
	5*	0.25		

* See text for details on the estimation of tester biases for model T, testers 3 and 5.

ences are statistically significant (at the five percent level) for either one or two testers for a given combination of pollutant and model.

The calculation for model T was a little more complicated due to the confounding of the tester effect for testers 3 and 5 with mileage interval and vehicle. Since tester 3 was the only tester for all model T vehicles at 40,000 miles, 45,000 miles, and 50,000 miles, the tester 3 effect cannot be separated from the mileage effect. Therefore we chose to assume that there was no tester 3 effect and that all variation at those mileage intervals is due to pollutant, vehicle and mileage effects only.

For tester 5 on model T the difficulty is that this tester was only used at 55,000 miles and was not used on the same vehicle as any other tester (either none or both emissions tests at 55,000 miles were performed by tester 3 on a given vehicle); therefore there are no comparisons available to estimate the tester 5 bias directly. For the purpose of estimating the tester 5 effect we made the assumption that the difference in vehicle-means for the three HiTEC 3000 vehicles at 55,000 miles (only) was due to tester bias and not to vehicle-to-vehicle variation. A similar assumption was made for the EEE vehicles. The tester 5 bias for each fuel was then estimated essentially by the difference between the average for the emissions tests using tester 5 and the average for the emissions tests using tester 1. The average tester 5 bias was estimated as the average of the biases for each fuel.

The detailed procedure used for estimating tester 5 bias for model T was as follows: First we adjusted the tester 2 emissions for vehicle 4 at 54,980 miles by adding back the estimated difference between tester 2 and tester 1 based on the above linear model (this estimable difference is reported in Table 2). This effectively divides the observations at 55,000 miles into those using tester 1 and those using tester 5. For each fuel the difference between the means for the tester 5 emissions tests and the tester 1 emissions tests estimates the effect of tester 5 compared to tester 1. The average difference across the two fuels is an estimate of the tester bias for tester 5. The result is given in Tables H-2 to H-4 for model T and tester 5.

The estimated tester effects given in the tables were added back to every emissions test on the models tested at ECS in data set ETHYL4S2 except for the tests using tester 1. For example the tester bias of tester 2 for HC on model D is -0.014. This means that tester 2 emissions are approximately 0.014 g/mi lower than the emissions from tester 1. Thus all HC emissions tests on model D using tester 2 are increased by 0.014 to produce estimates of emissions using tester 1. The new data set, ETHYL4S4, was used to estimate the mean effect of HiTEC 3000 after adjusting for tester bias; a data listing for ETHYL4S4 is provided in Attachment A.

Attachment B

DATA PLOTS FOR DATA SET ETHYL4S2

Attachment B
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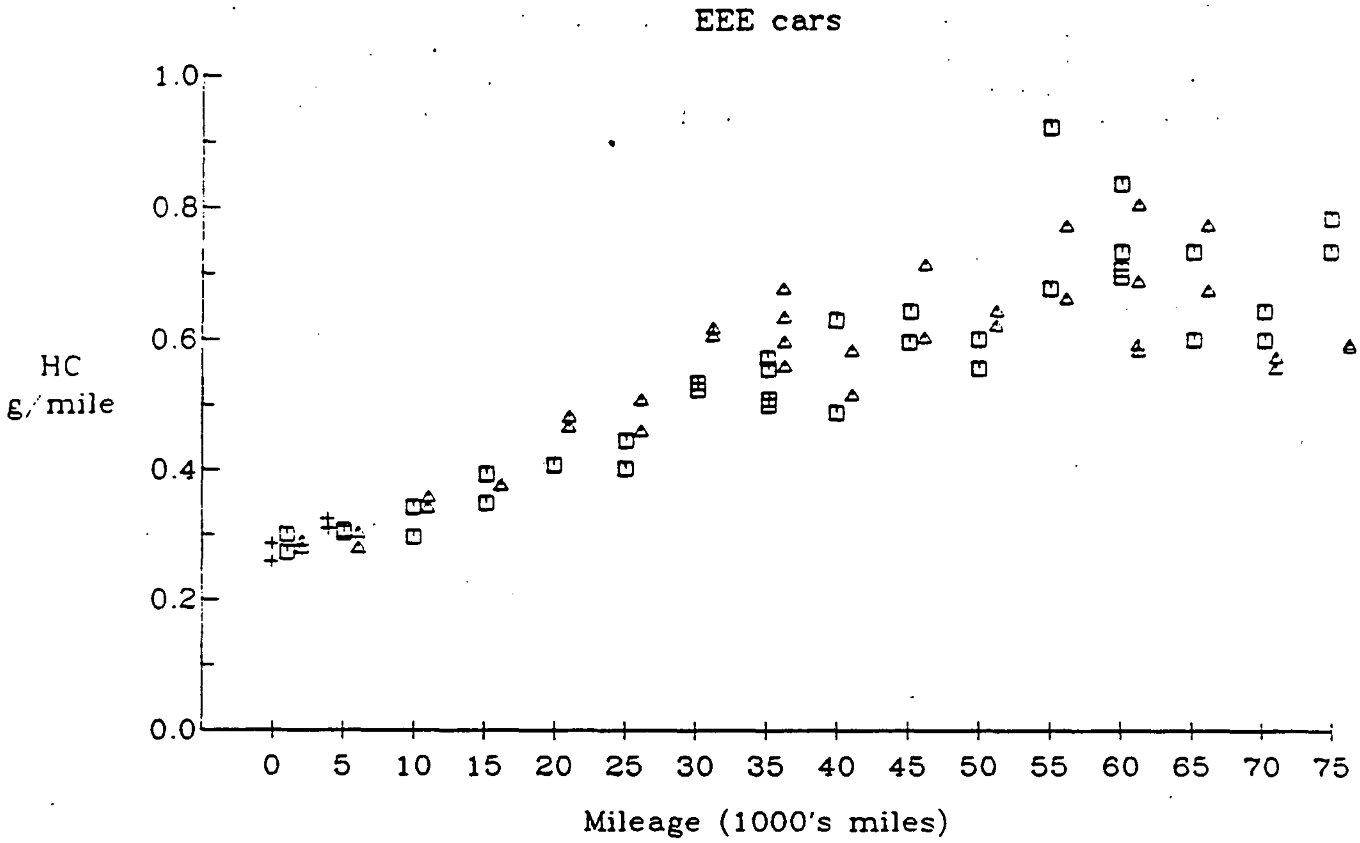
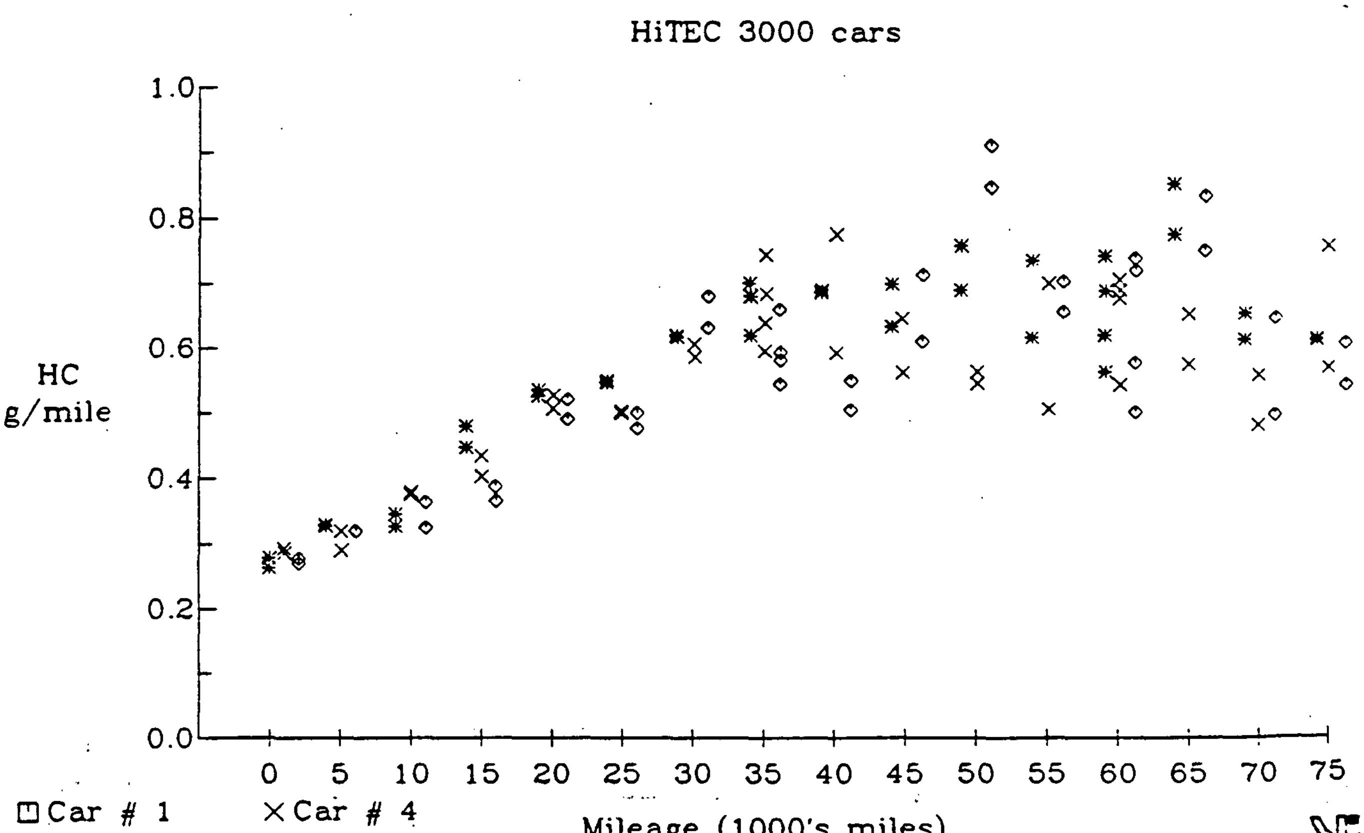
Tailpipe Hydrocarbon Emissions for Model Group D





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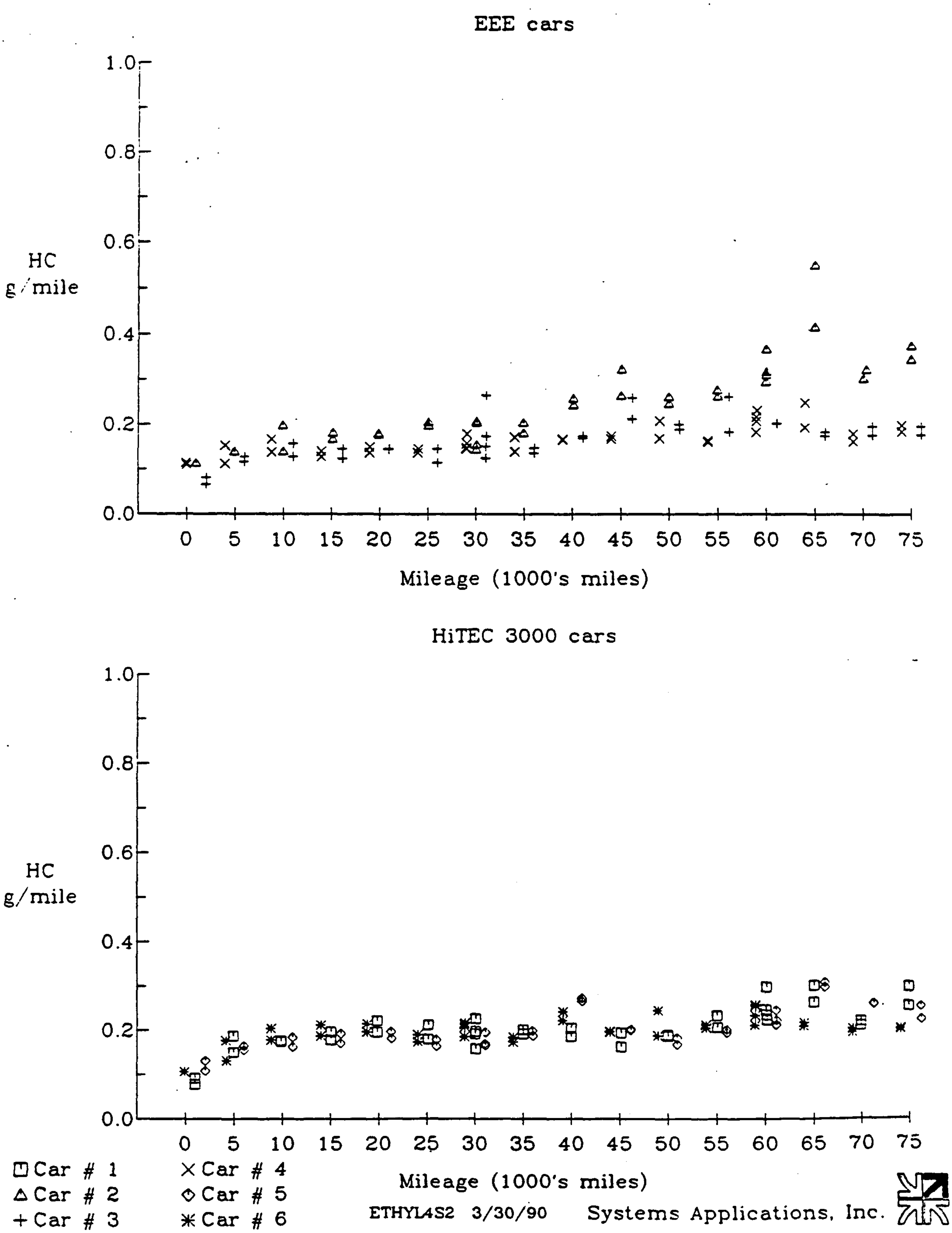
ETHYL4S2 3/30/90 Systems Applications, Inc.

Tailpipe Hydrocarbon Emissions for Model Group E



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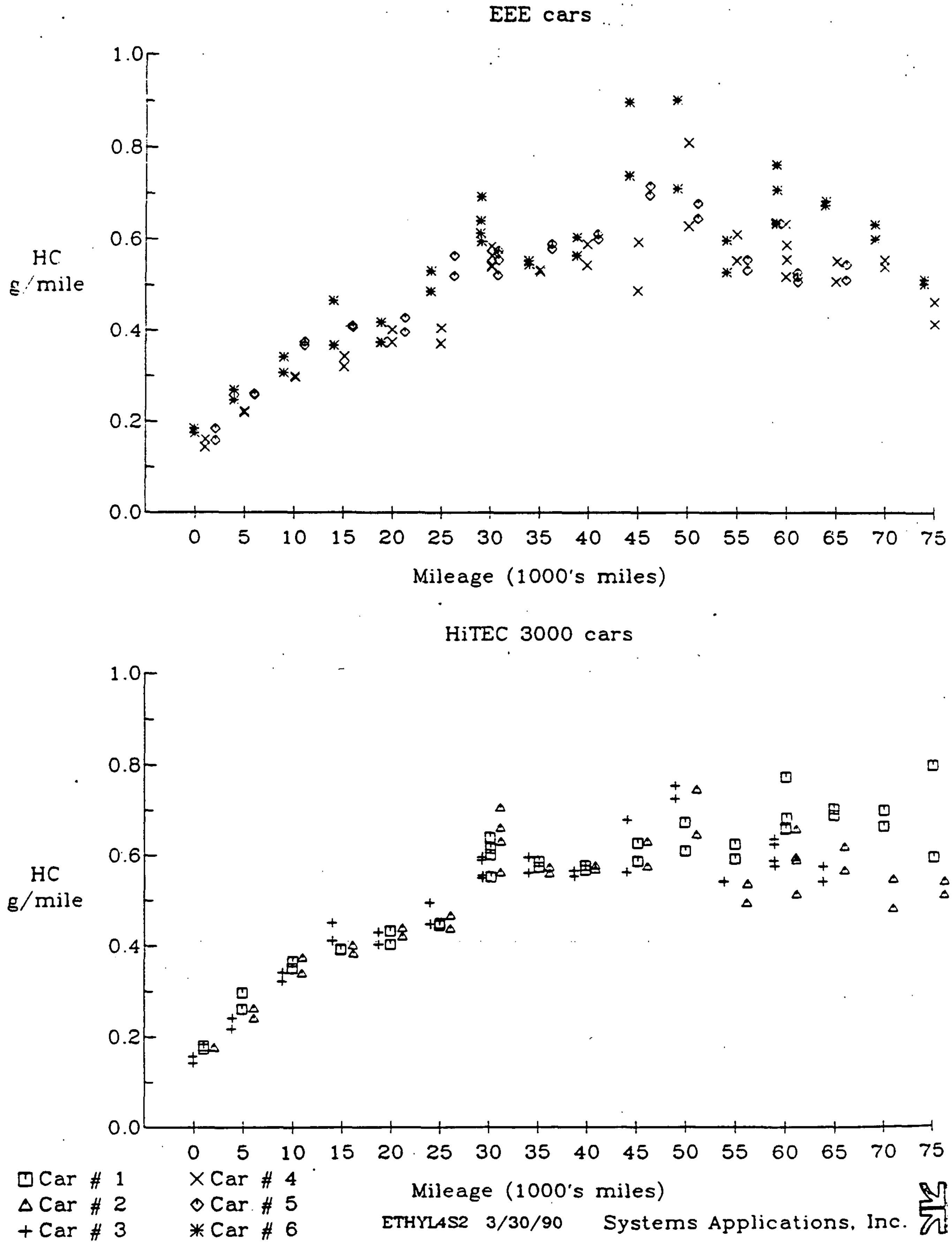
Tailpipe Hydrocarbon Emissions for Model Group F



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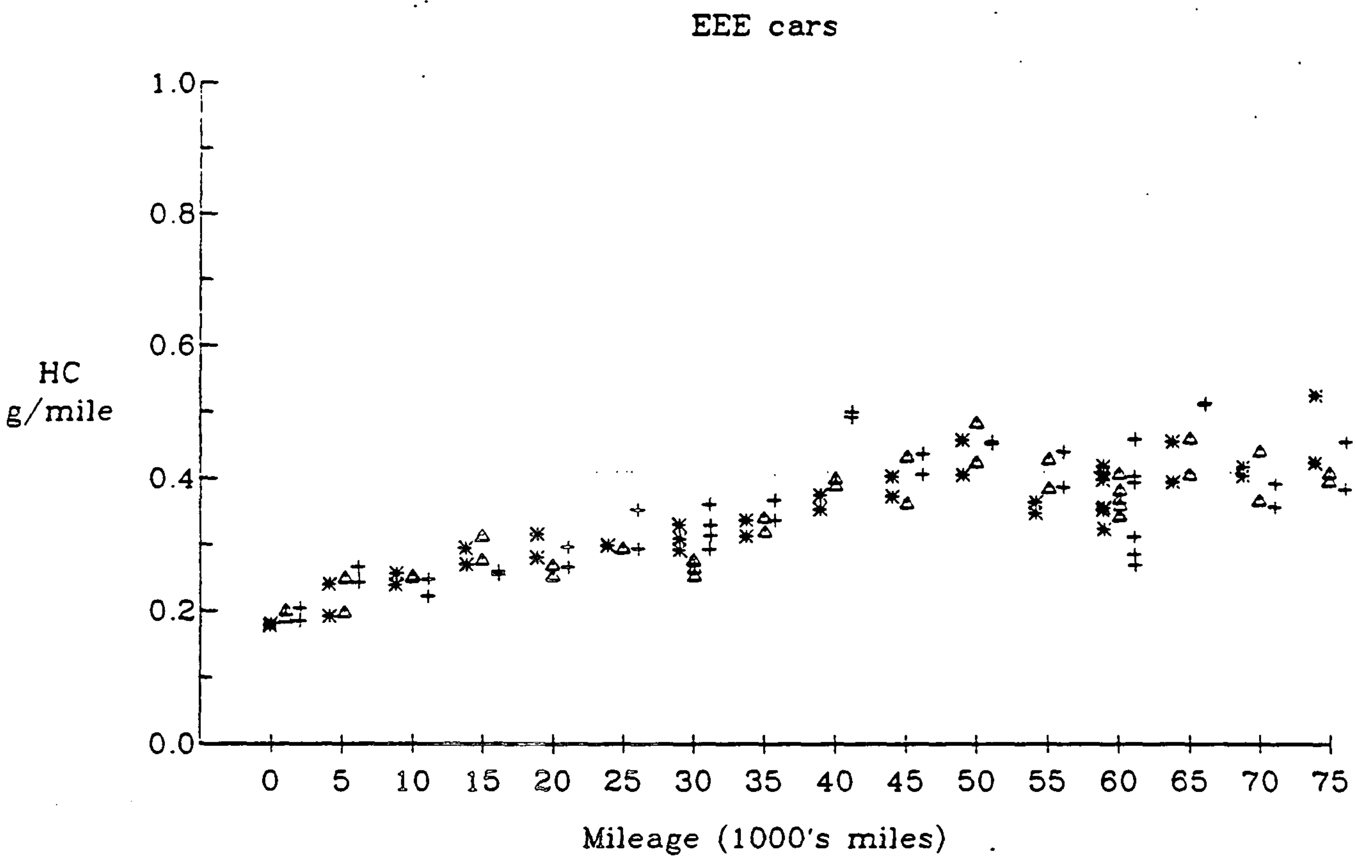

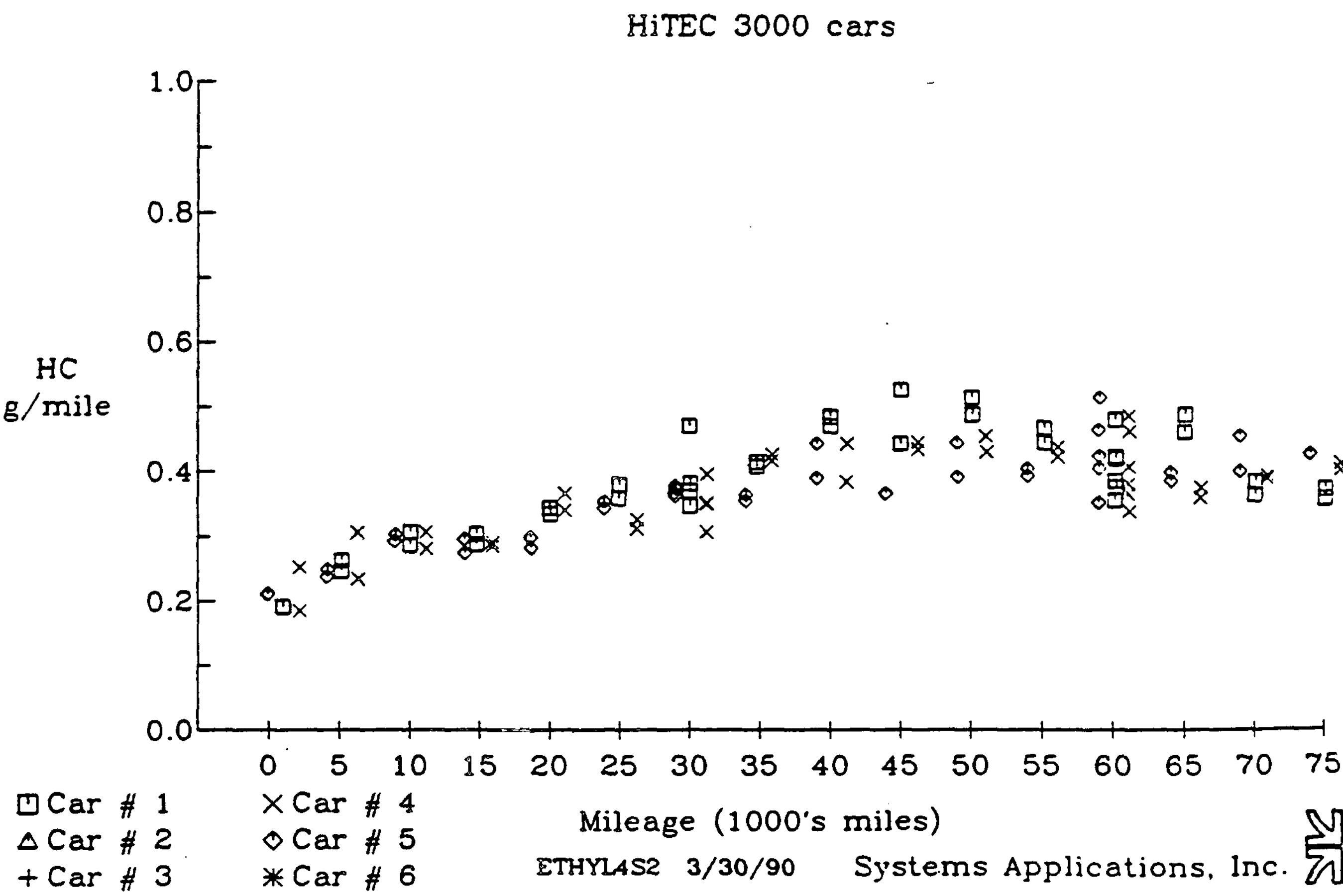

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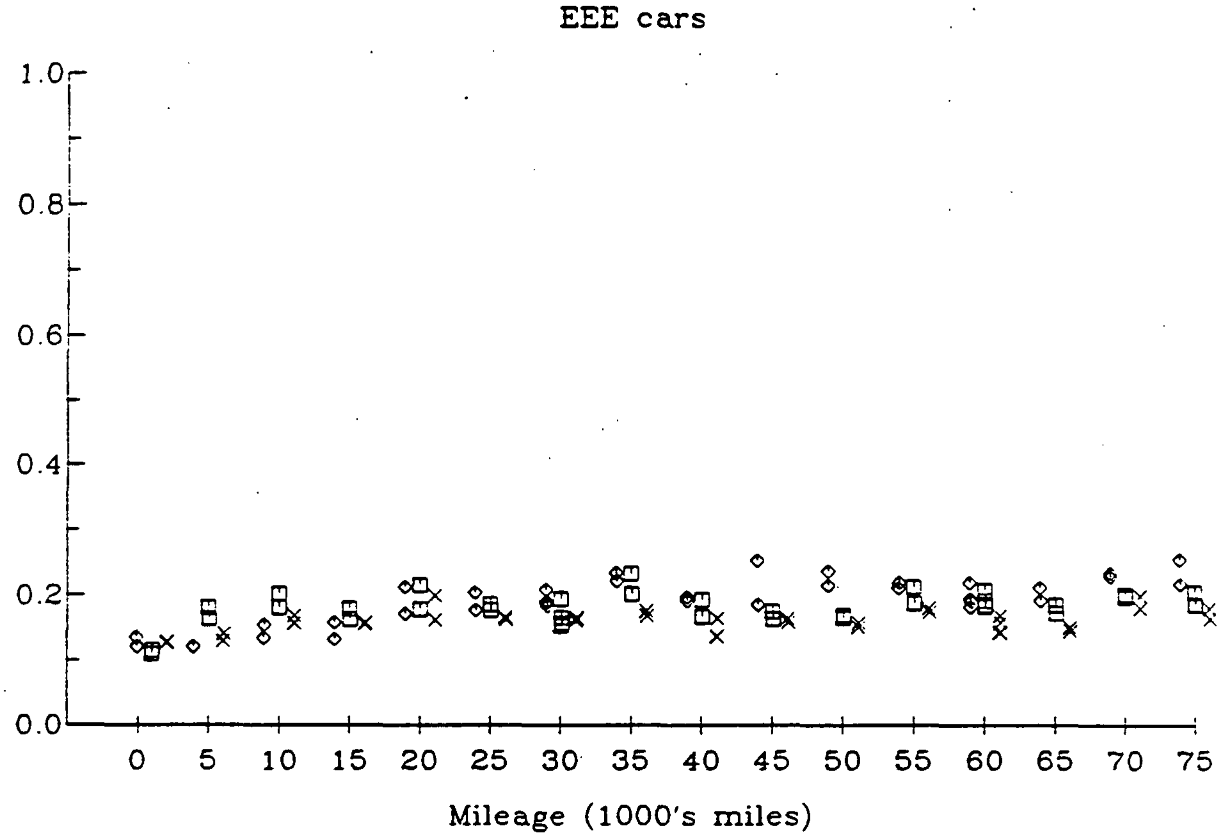

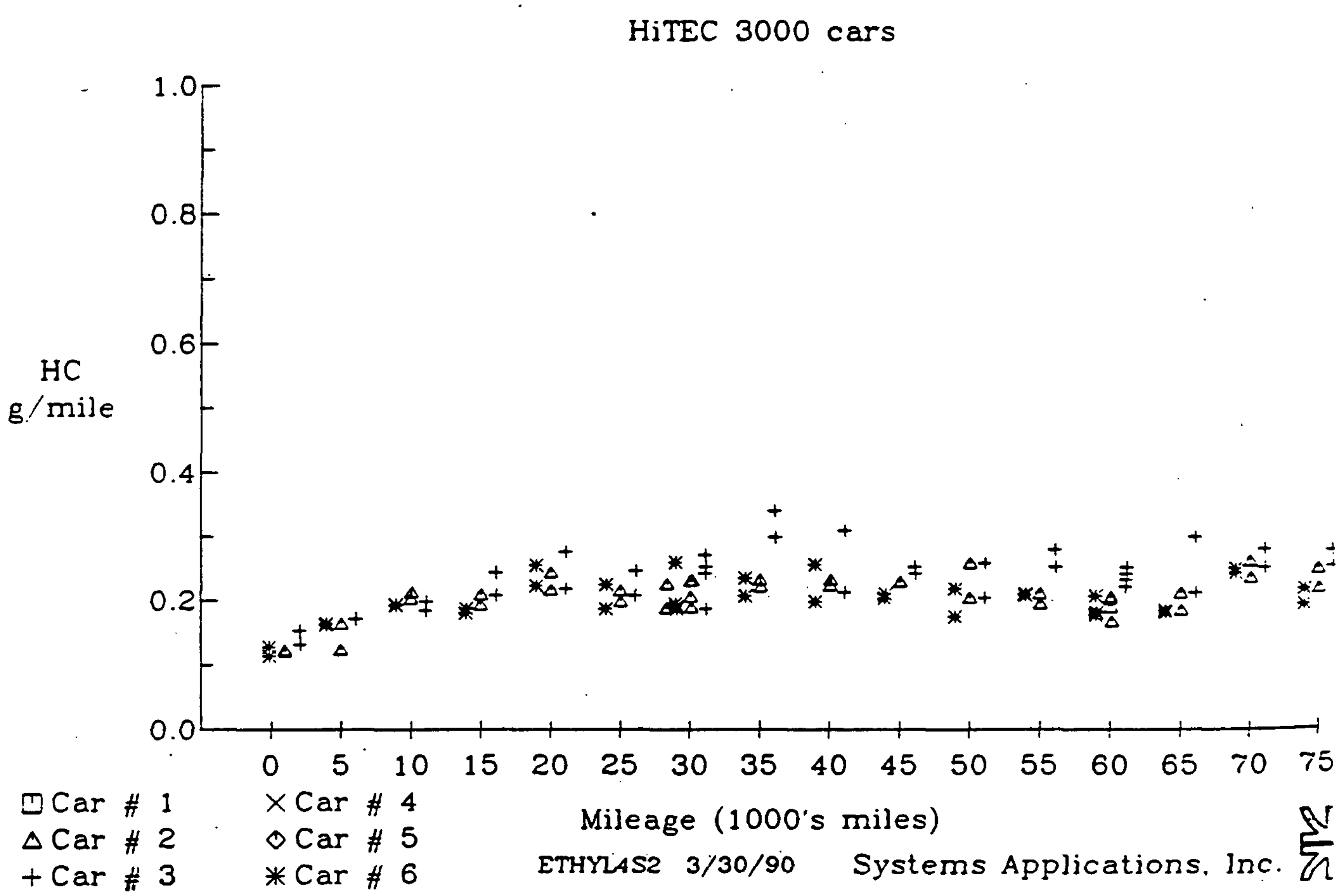

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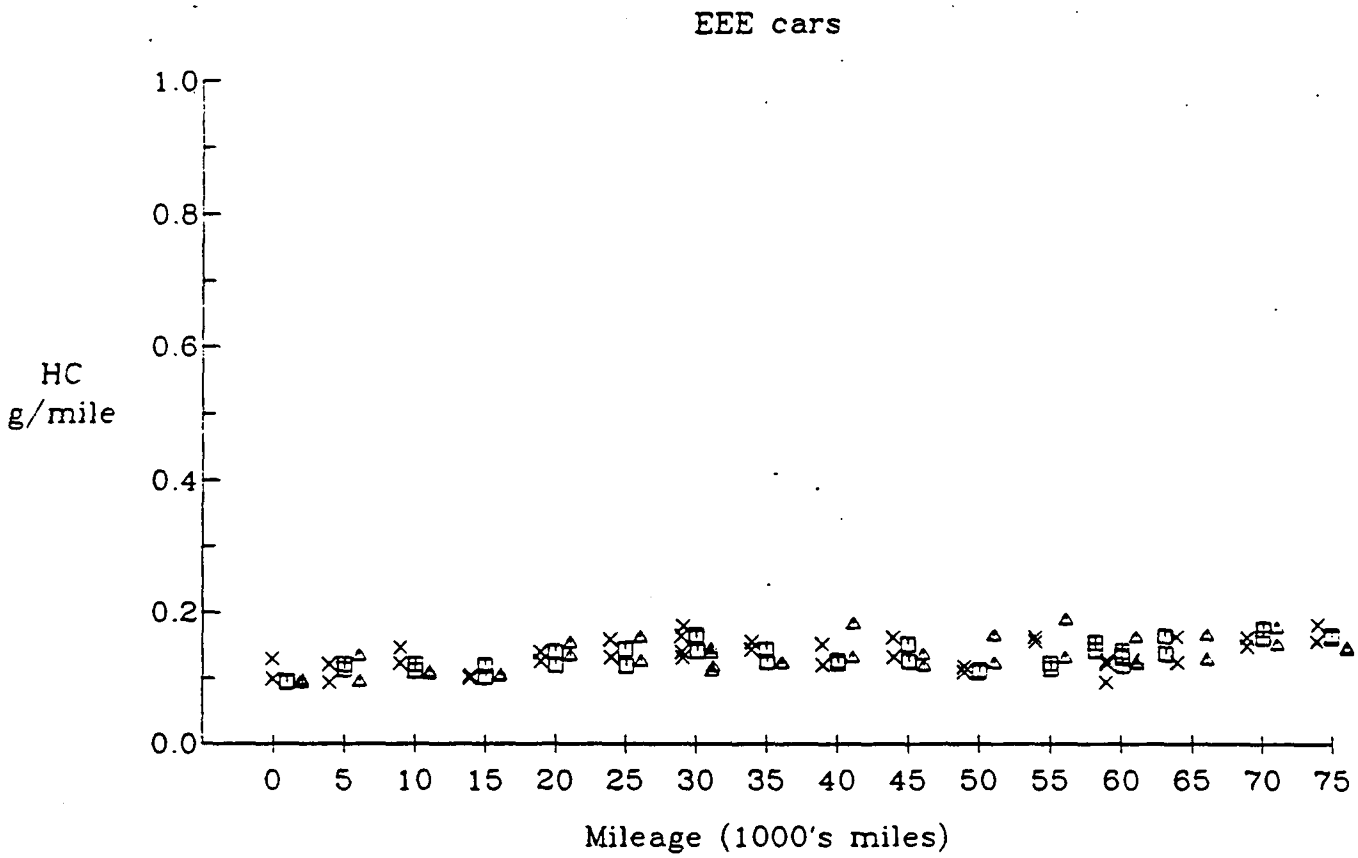

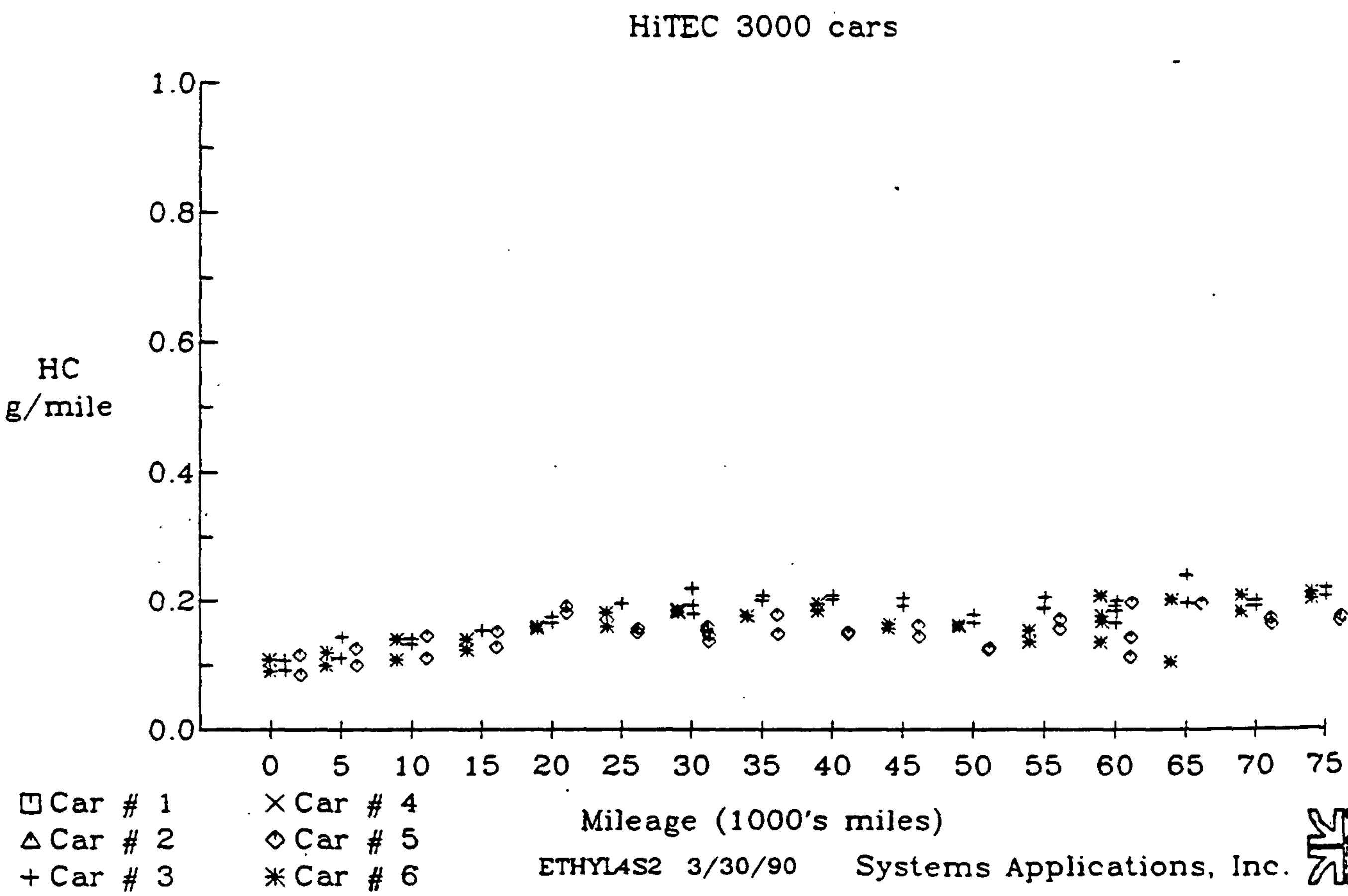

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Tailpipe Hydrocarbon Emissions for Model Group H

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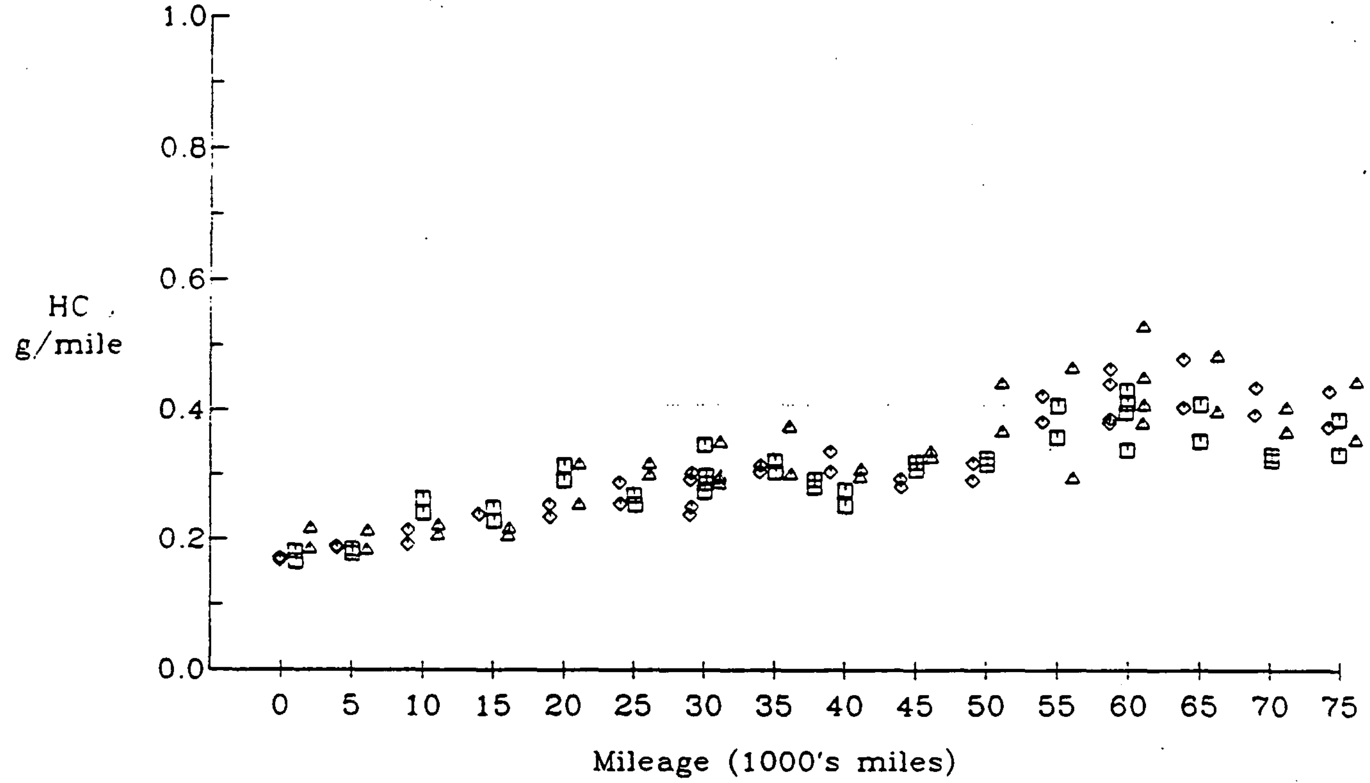

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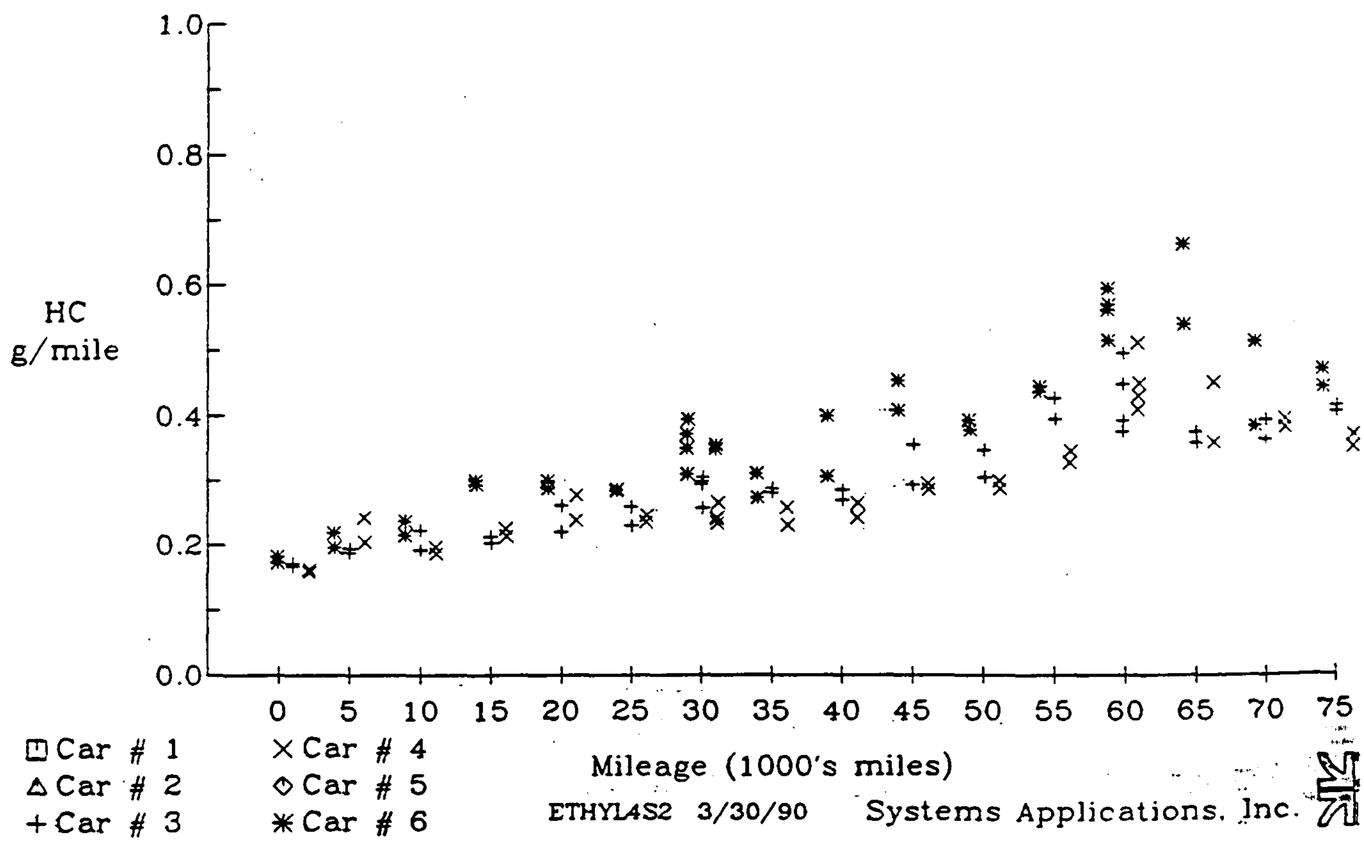

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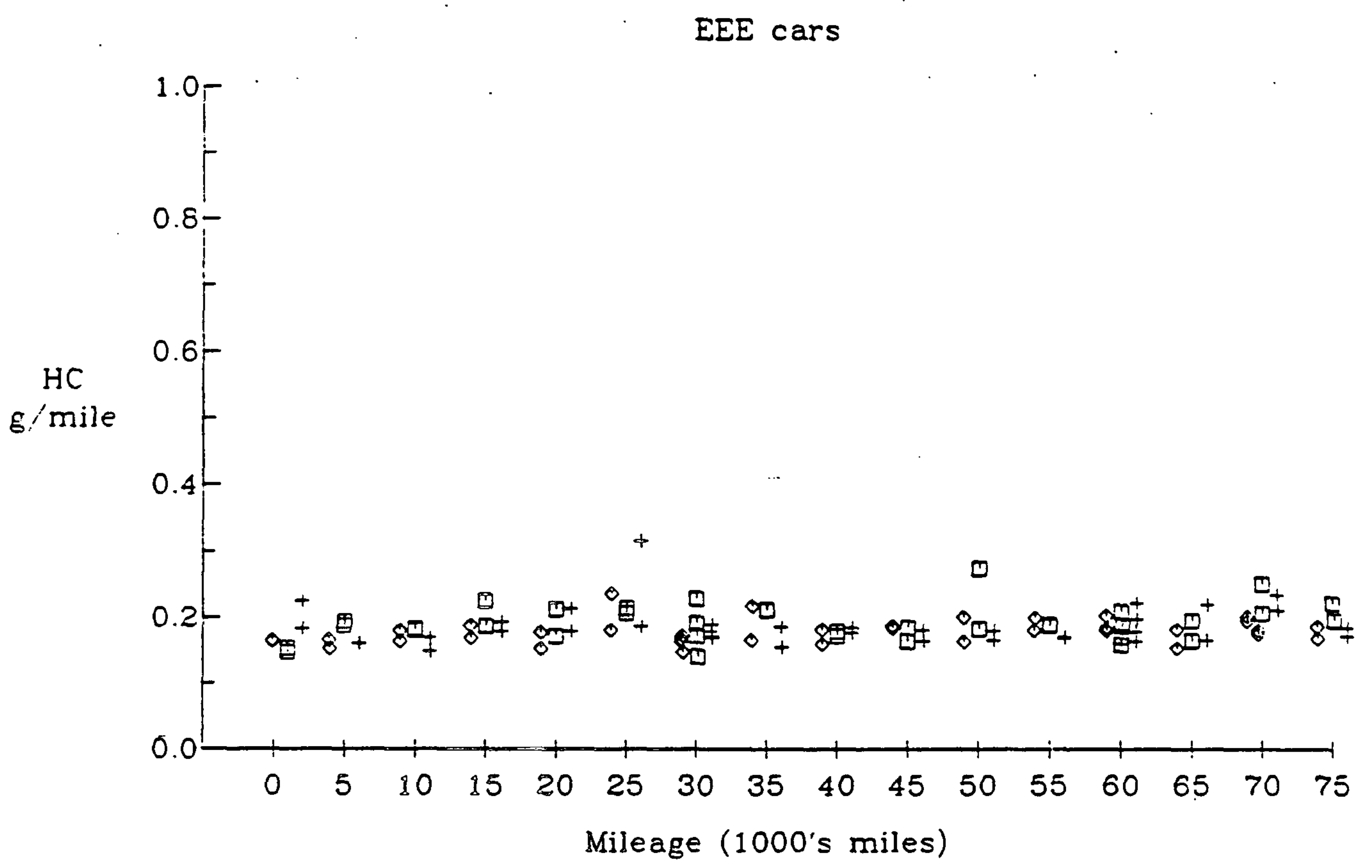
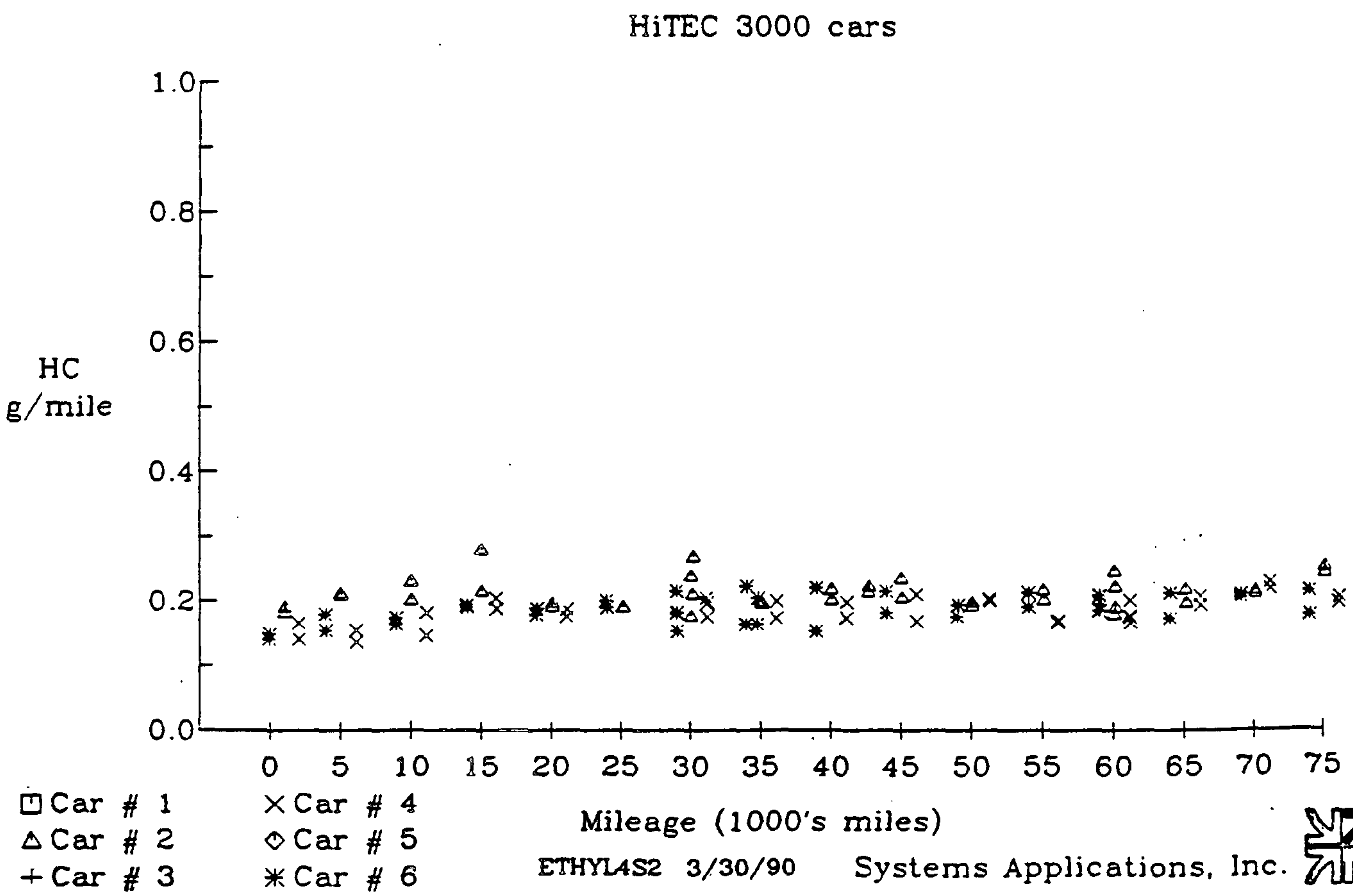
Tailpipe Hydrocarbon Emissions for Model Group I





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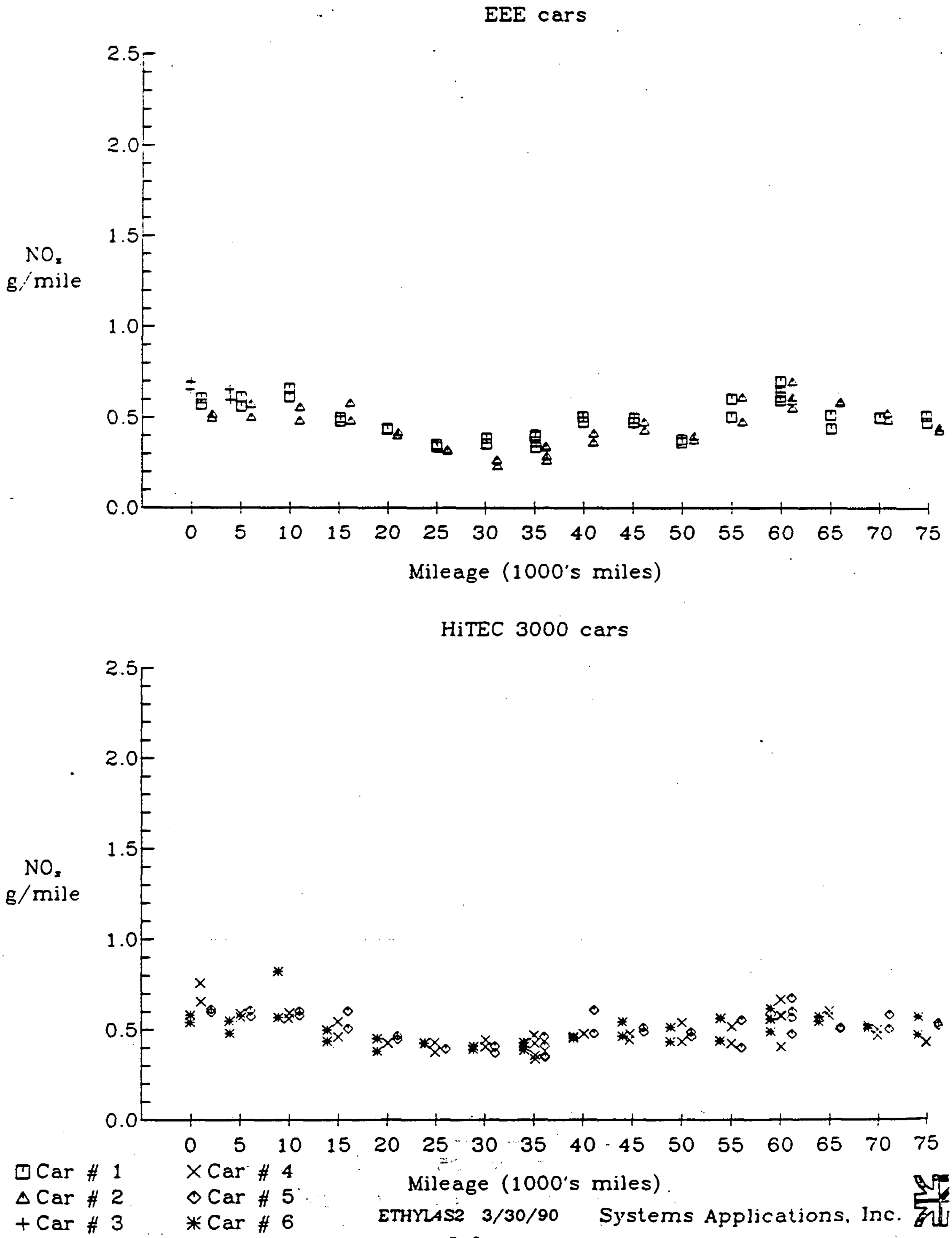

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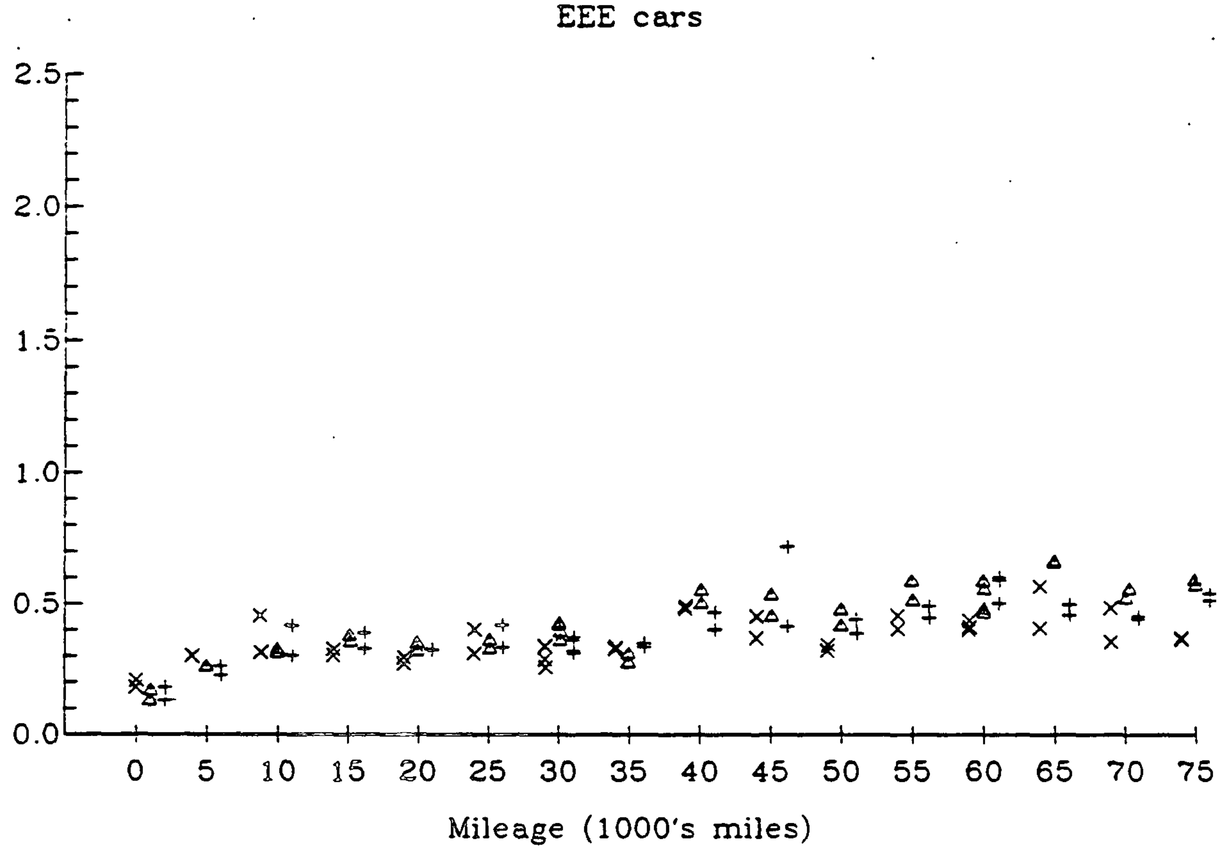

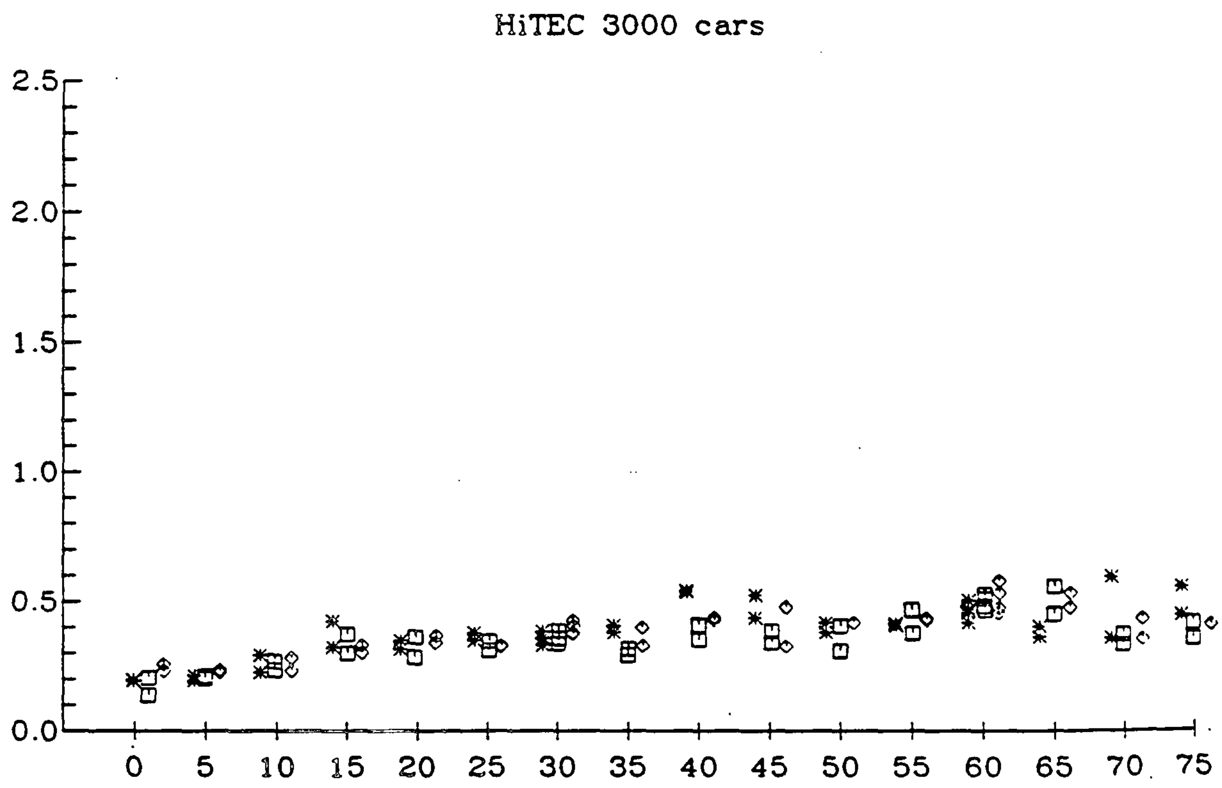

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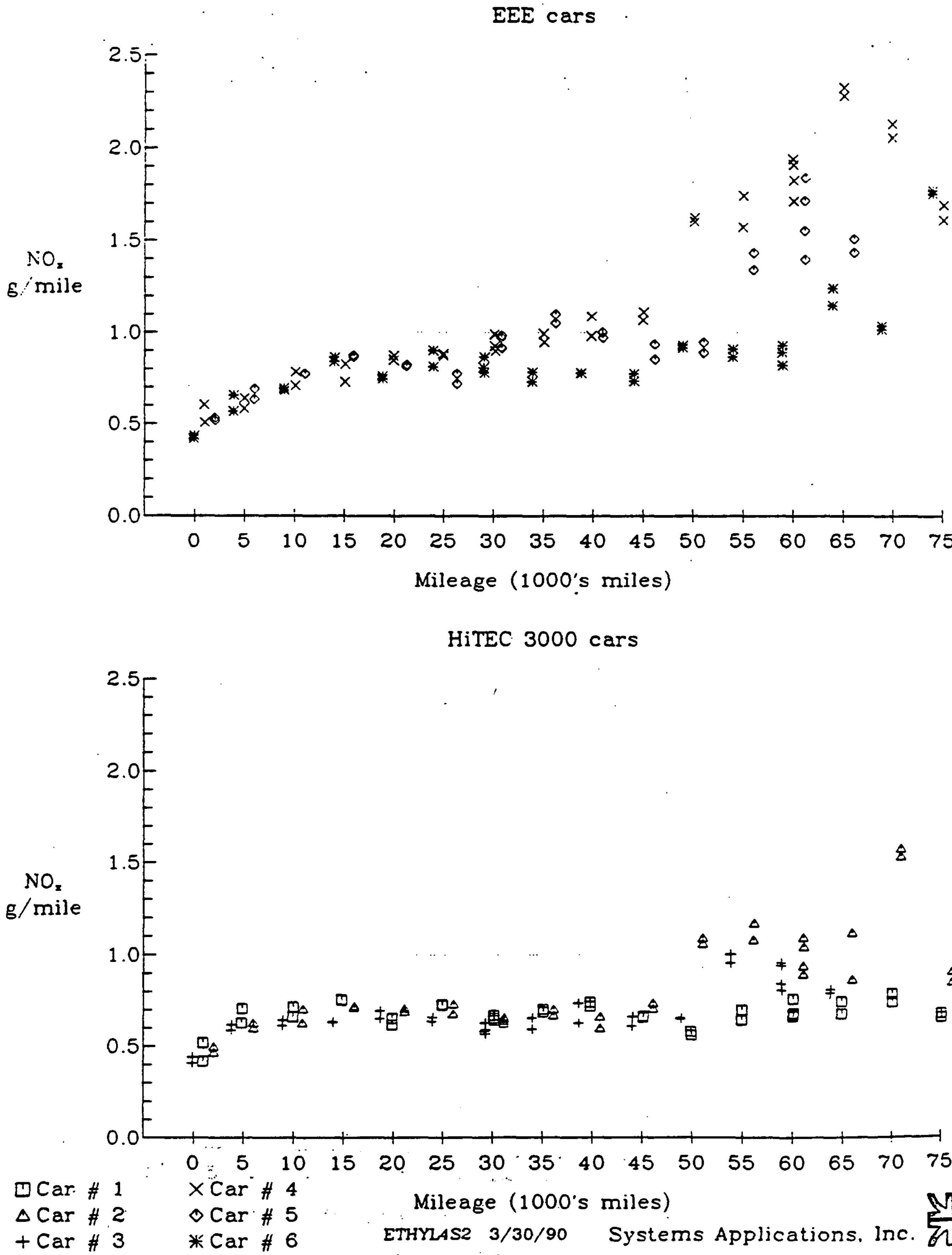
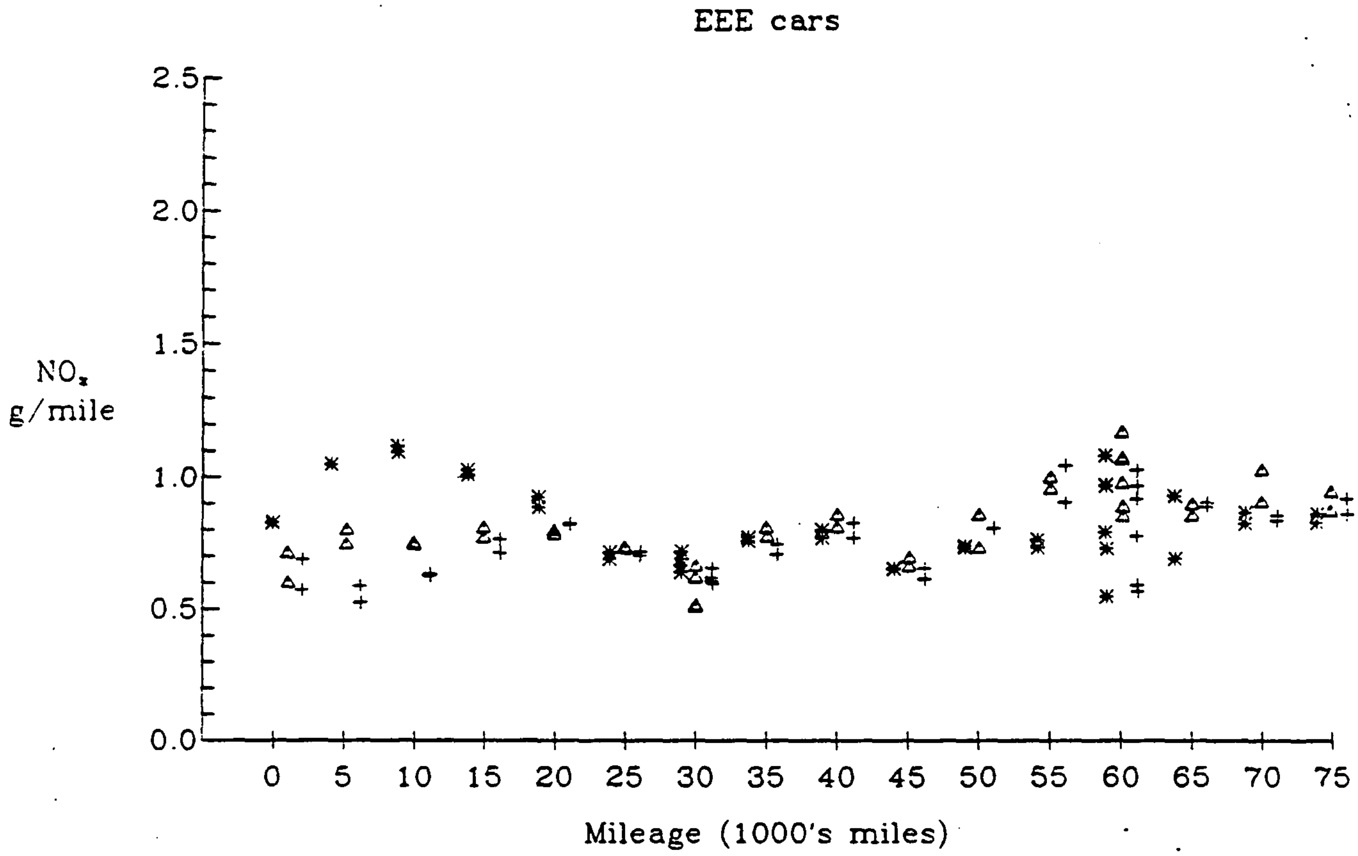
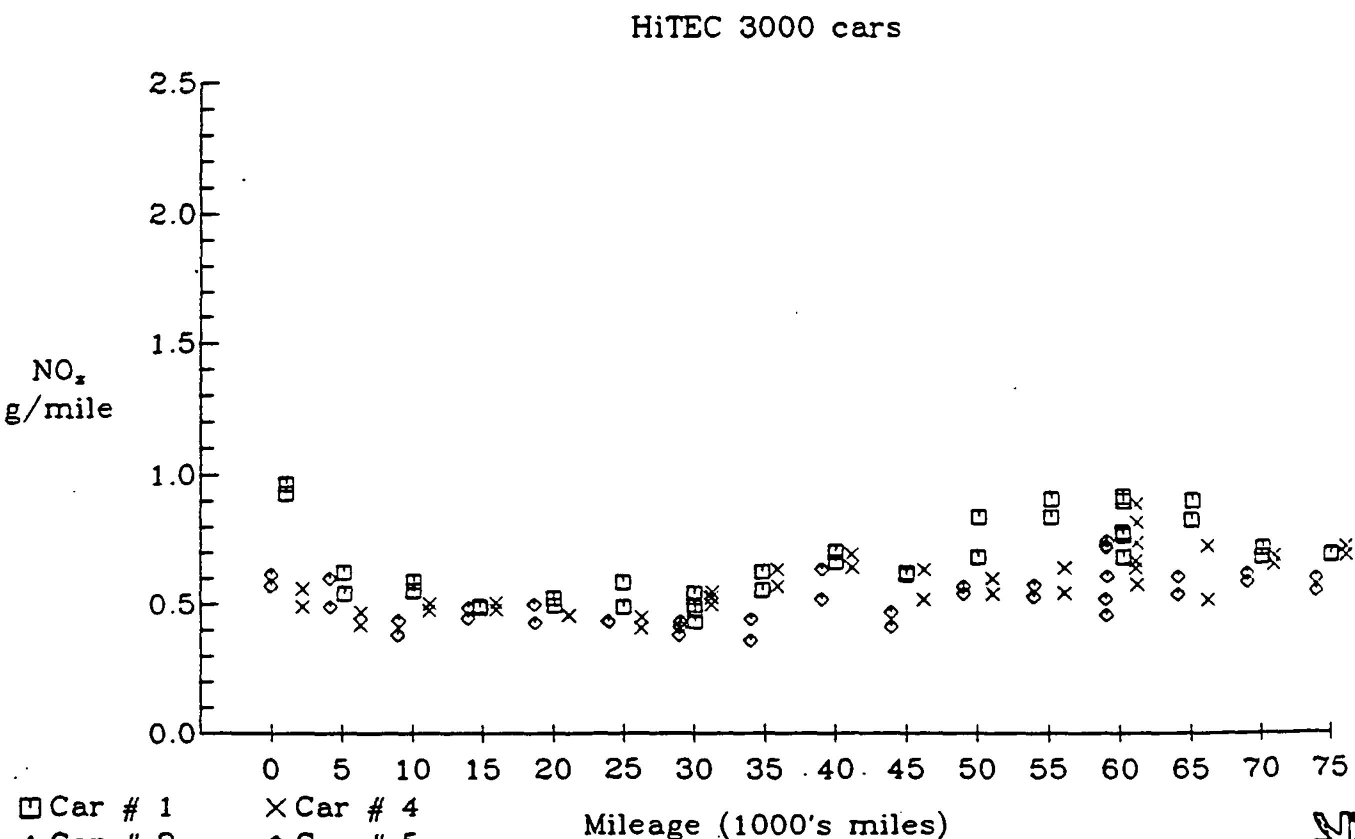
Tailpipe Nitrogen Oxides Emissions for Model Group F



ETHYL4S2 3/30/90 Systems Applications, Inc.

Tailpipe Nitrogen Oxides Emissions for Model Group T

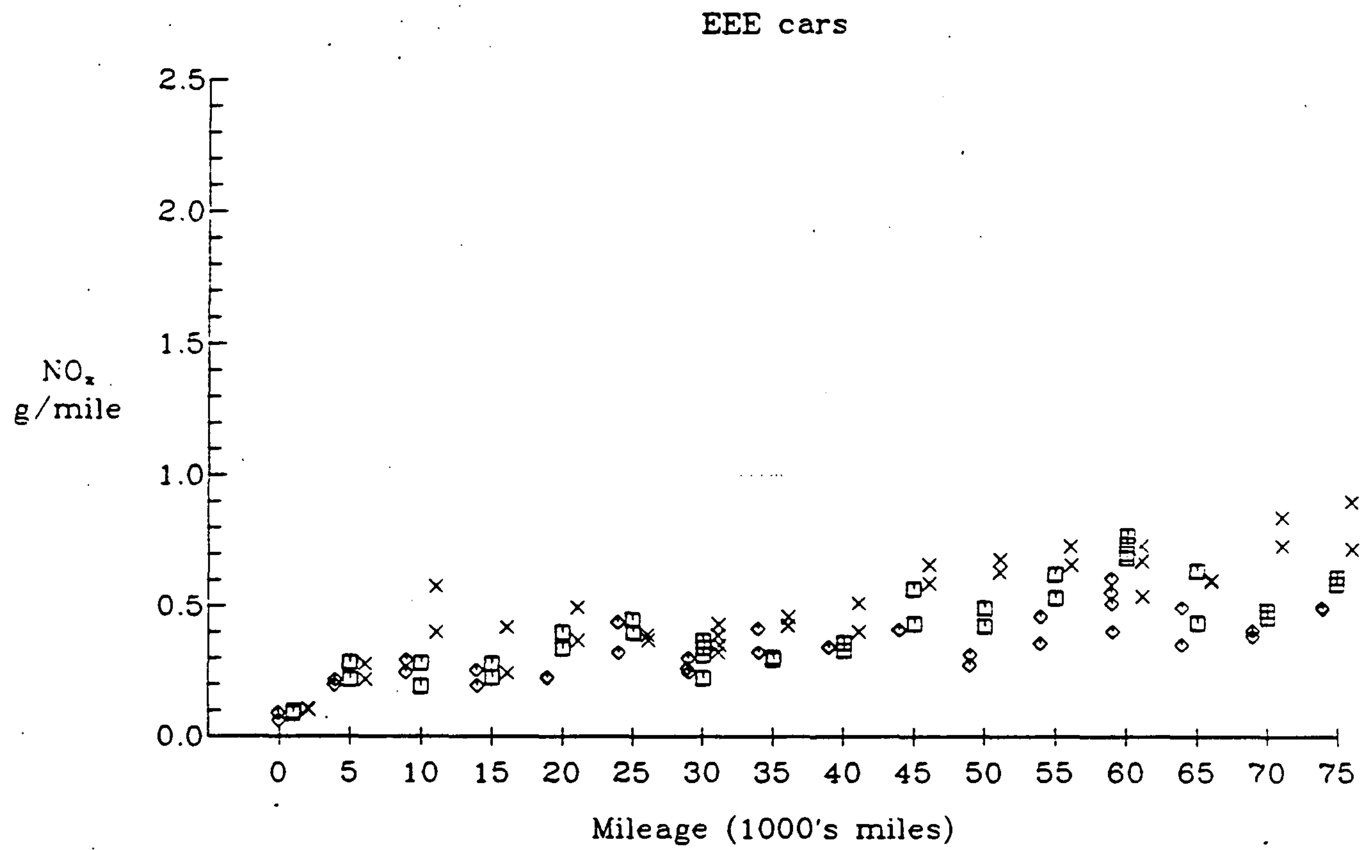


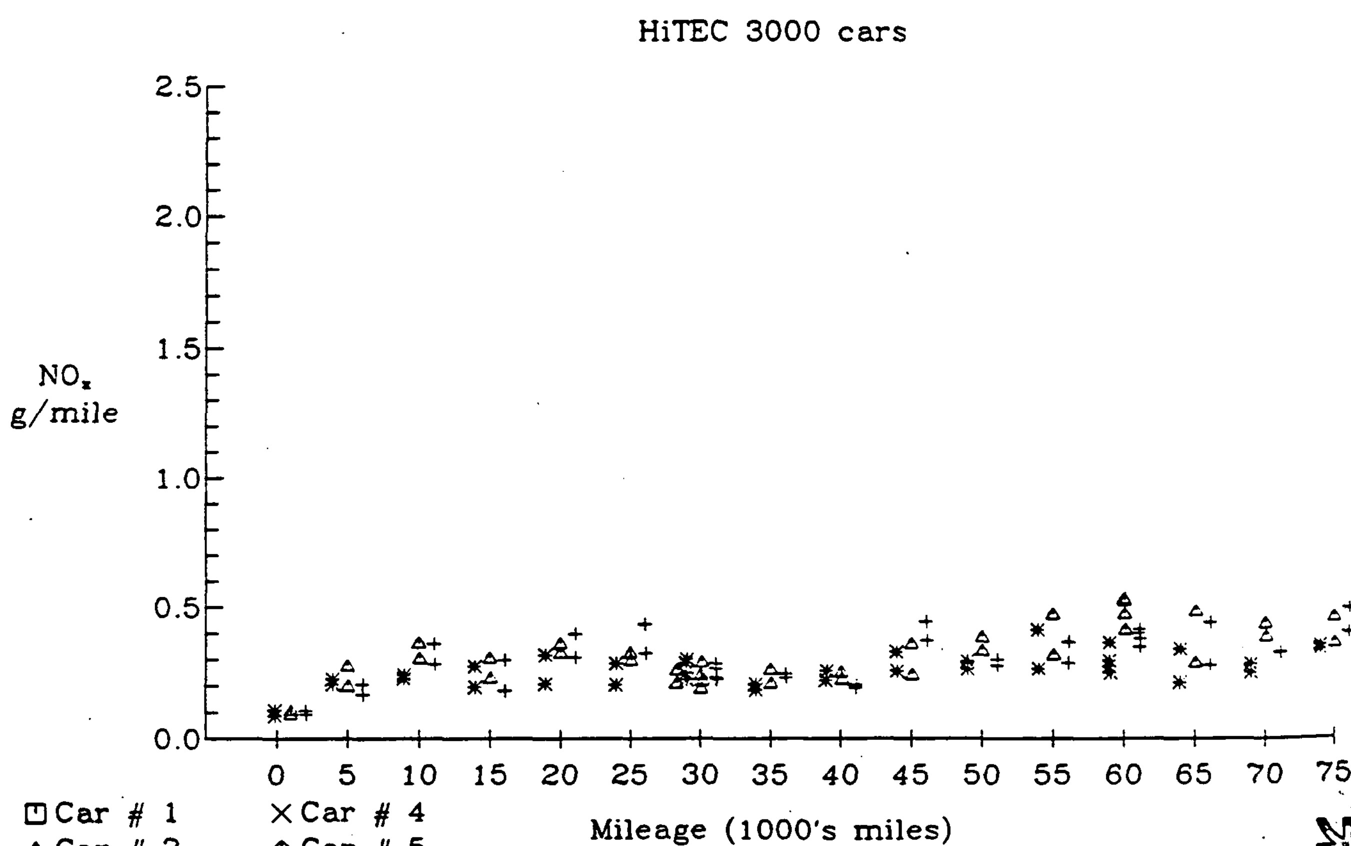


□ Car # 1
△ Car # 2
+ Car # 3
× Car # 4
◇ Car # 5
✳ Car # 6

ETHYL4S2 3/30/90 Systems Applications, Inc.

Tailpipe Nitrogen Oxides Emissions for Model Group C

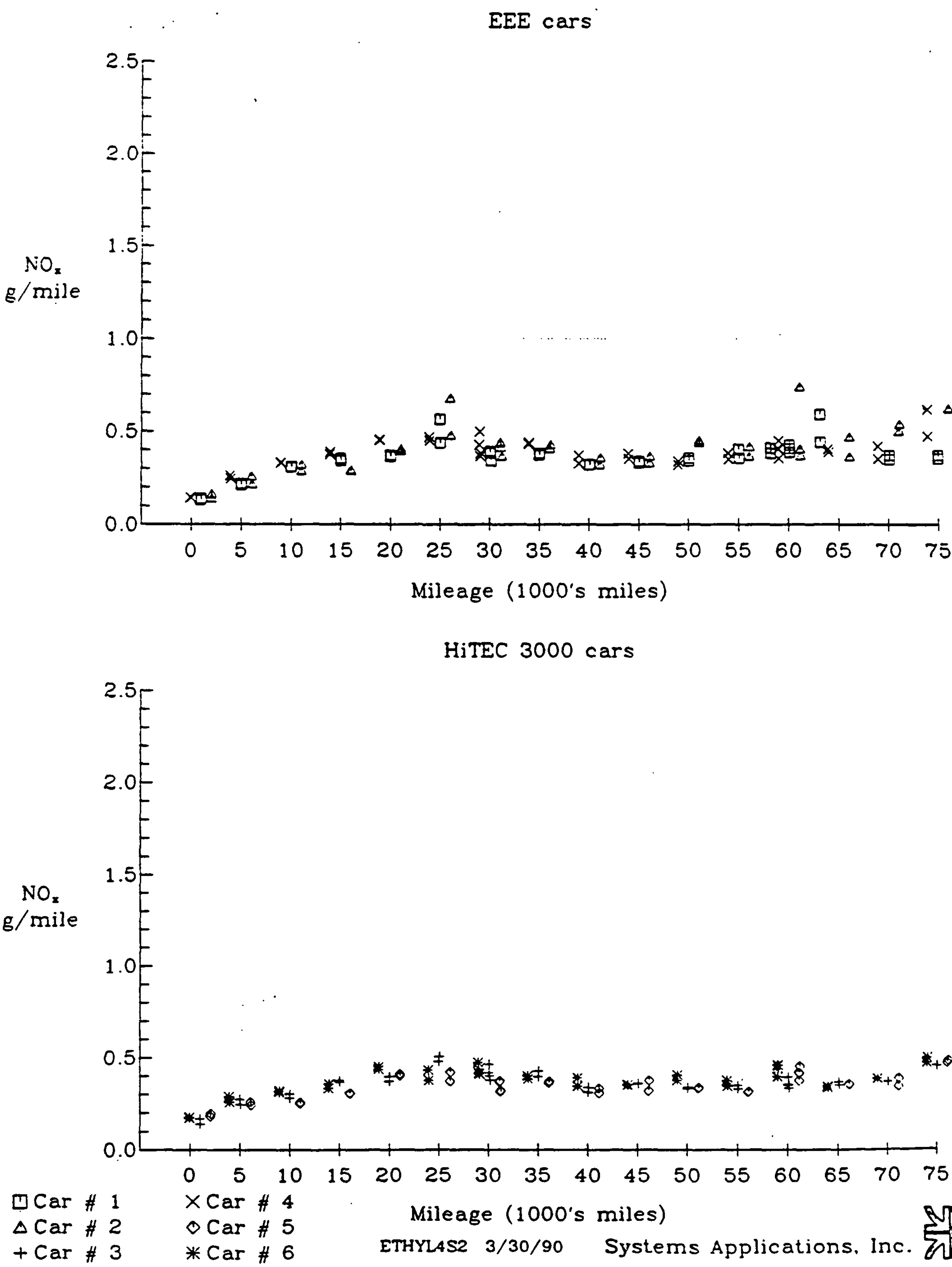




□ Car # 1 △ Car # 2 + Car # 3 × Car # 4 ◇ Car # 5 ✳ Car # 6

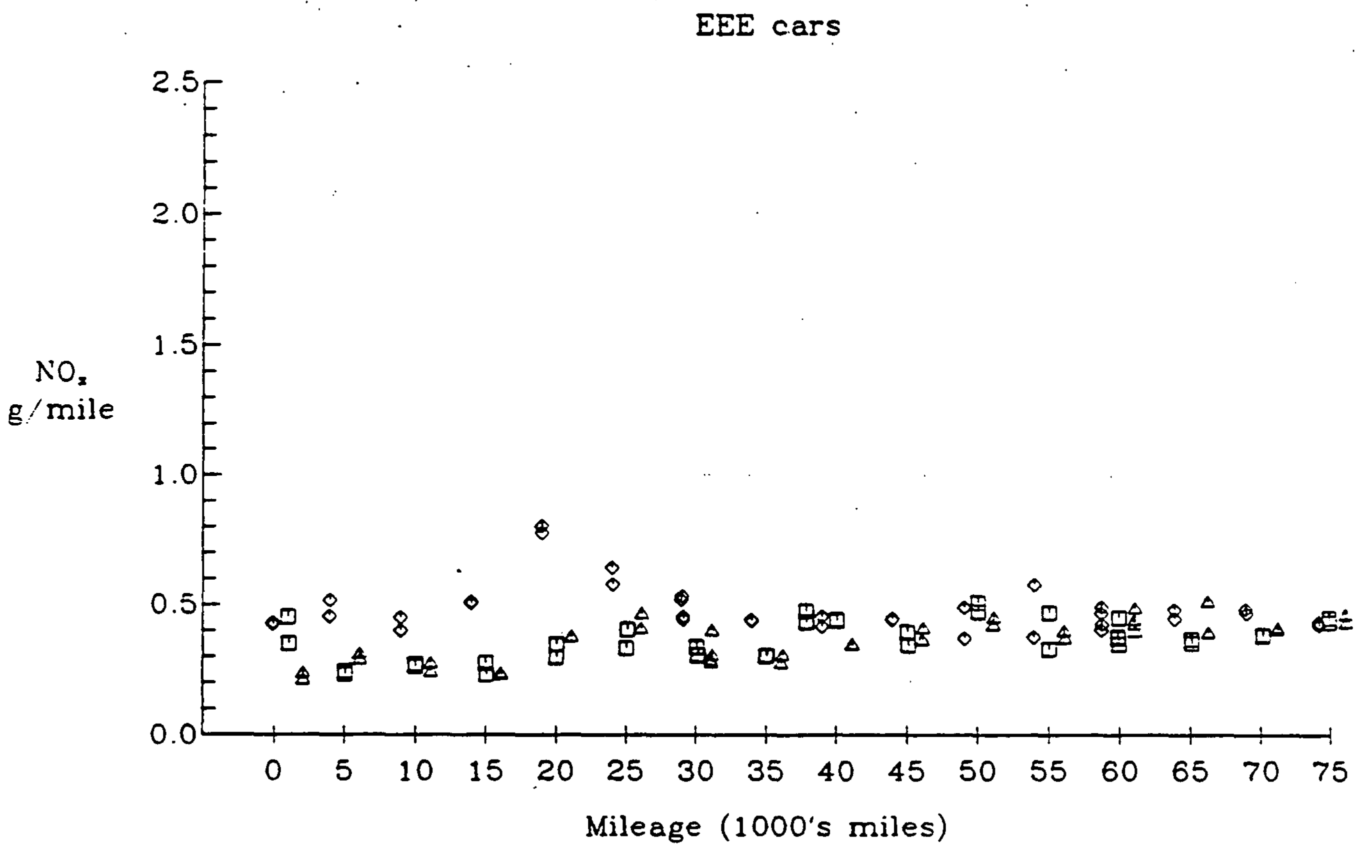
ETHYL4S2 3/30/90 Systems Applications, Inc.

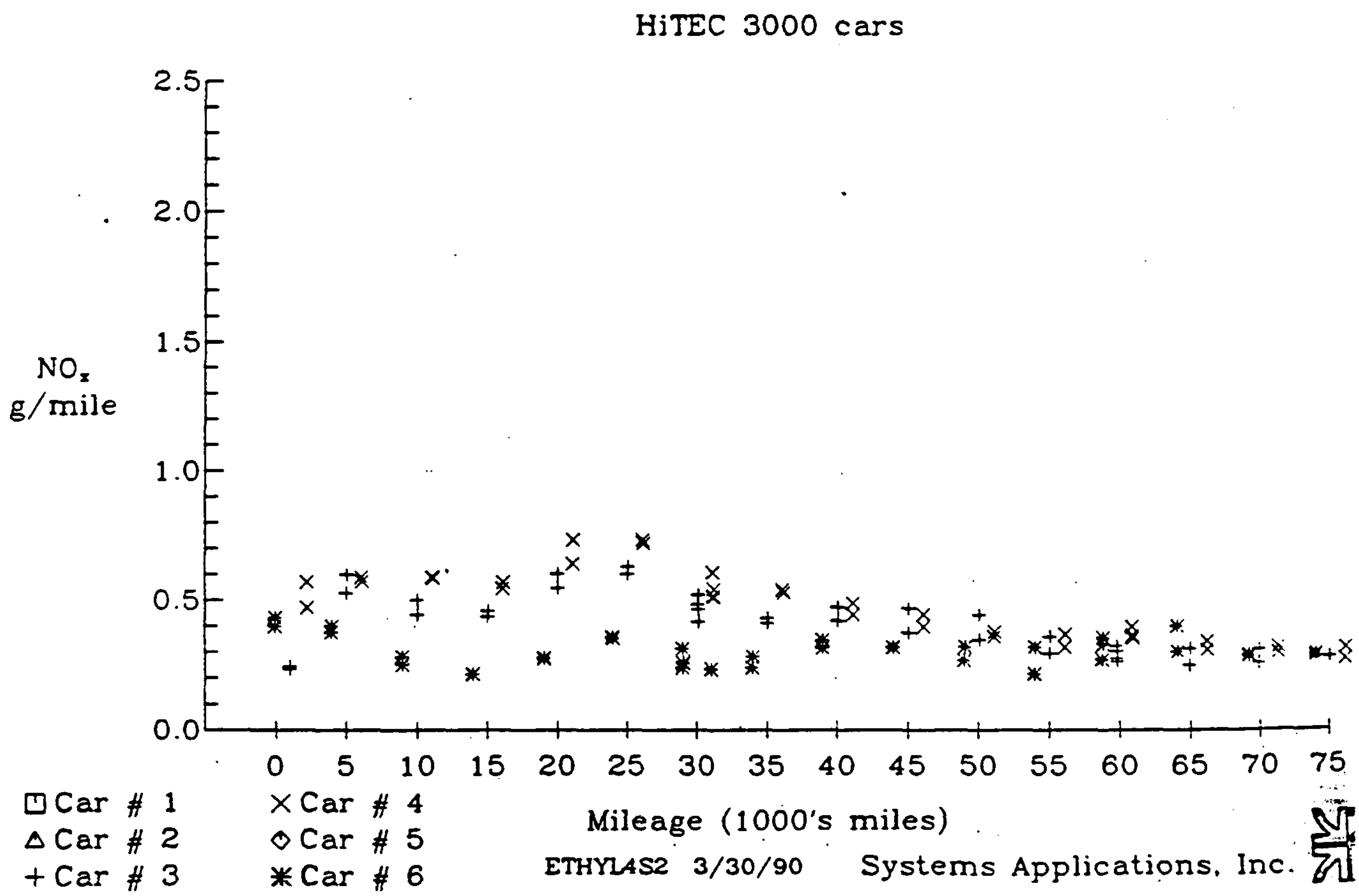
Tailpipe Nitrogen Oxides Emissions for Model Group G



ETHYL4S2 3/30/90 Systems Applications, Inc.

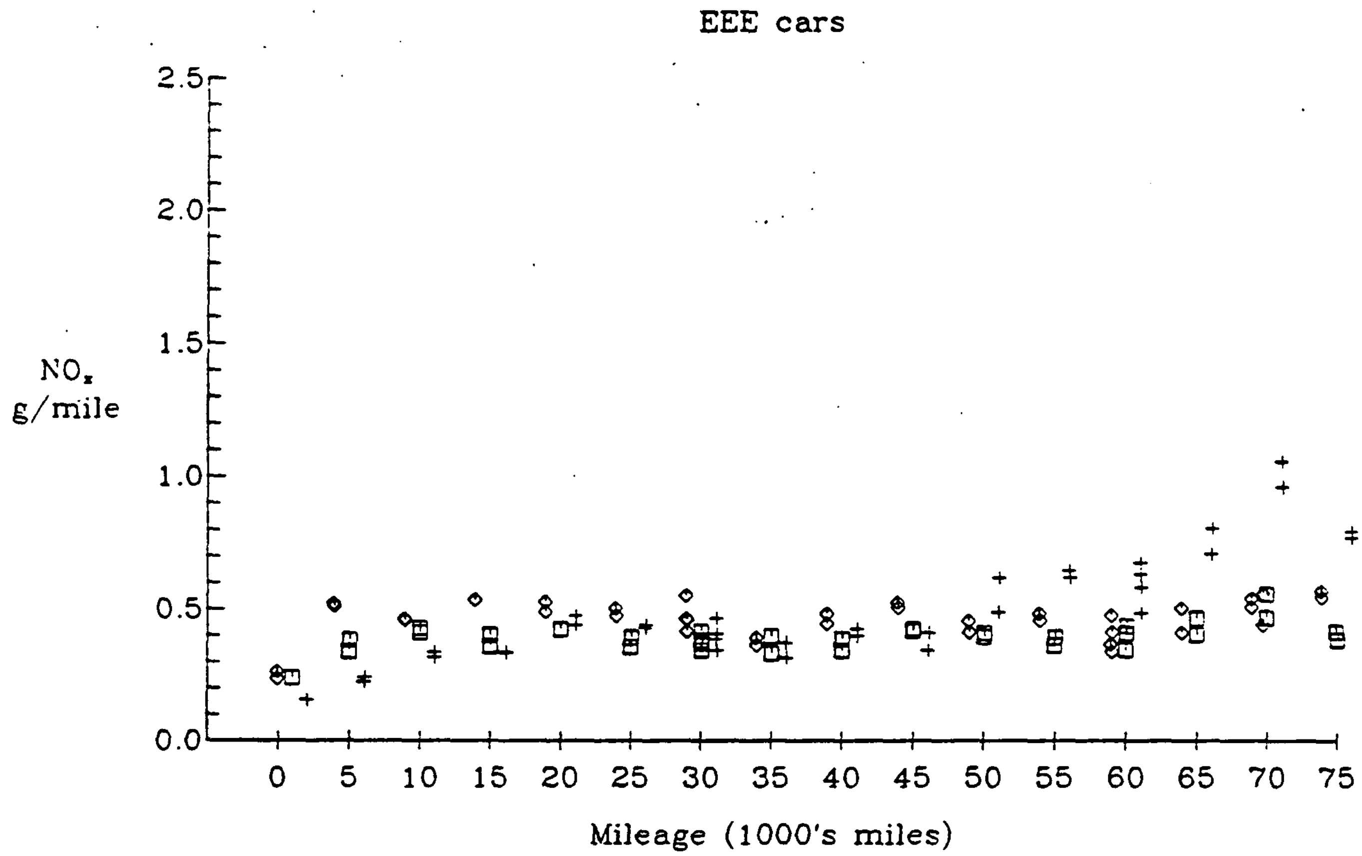
Tailpipe Nitrogen Oxides Emissions for Model Group H

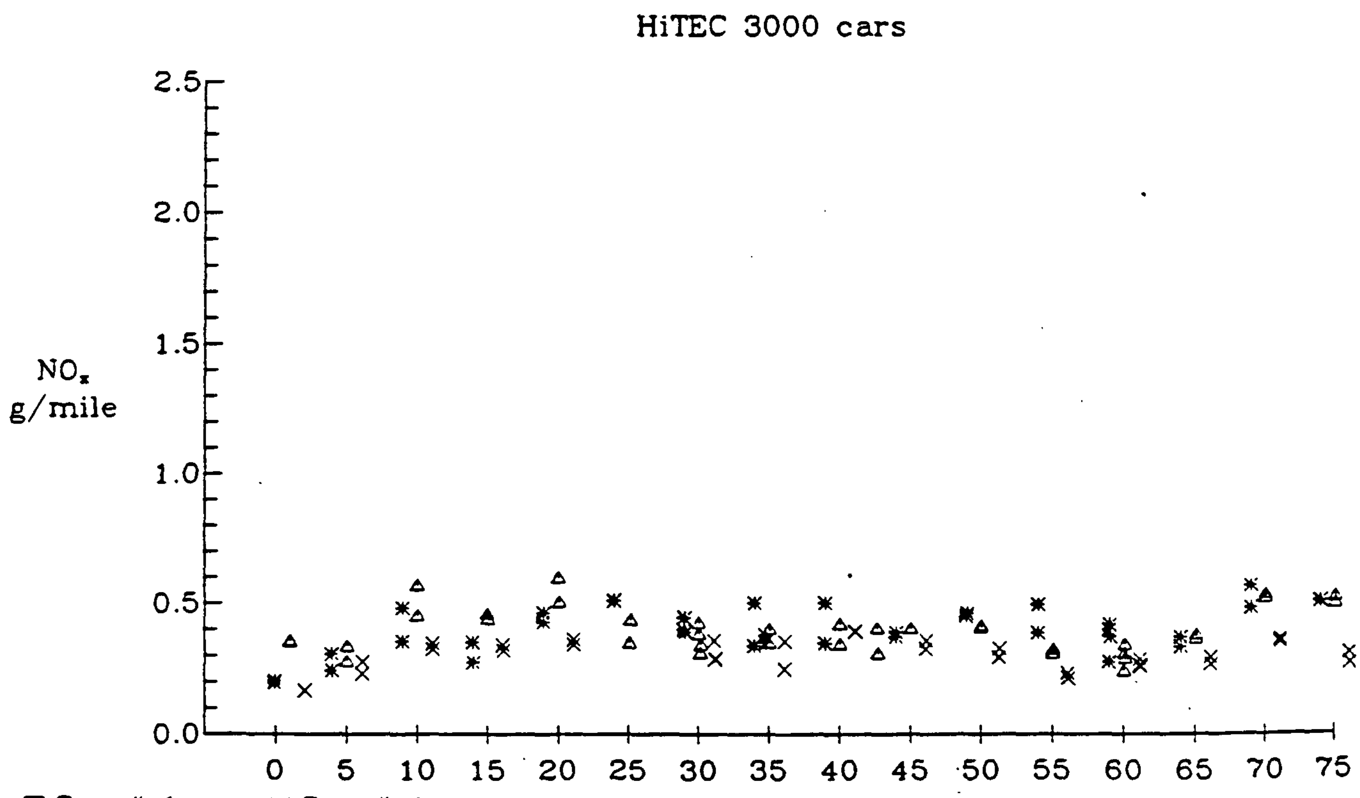




ETHYL4S2 3/30/90 Systems Applications, Inc.

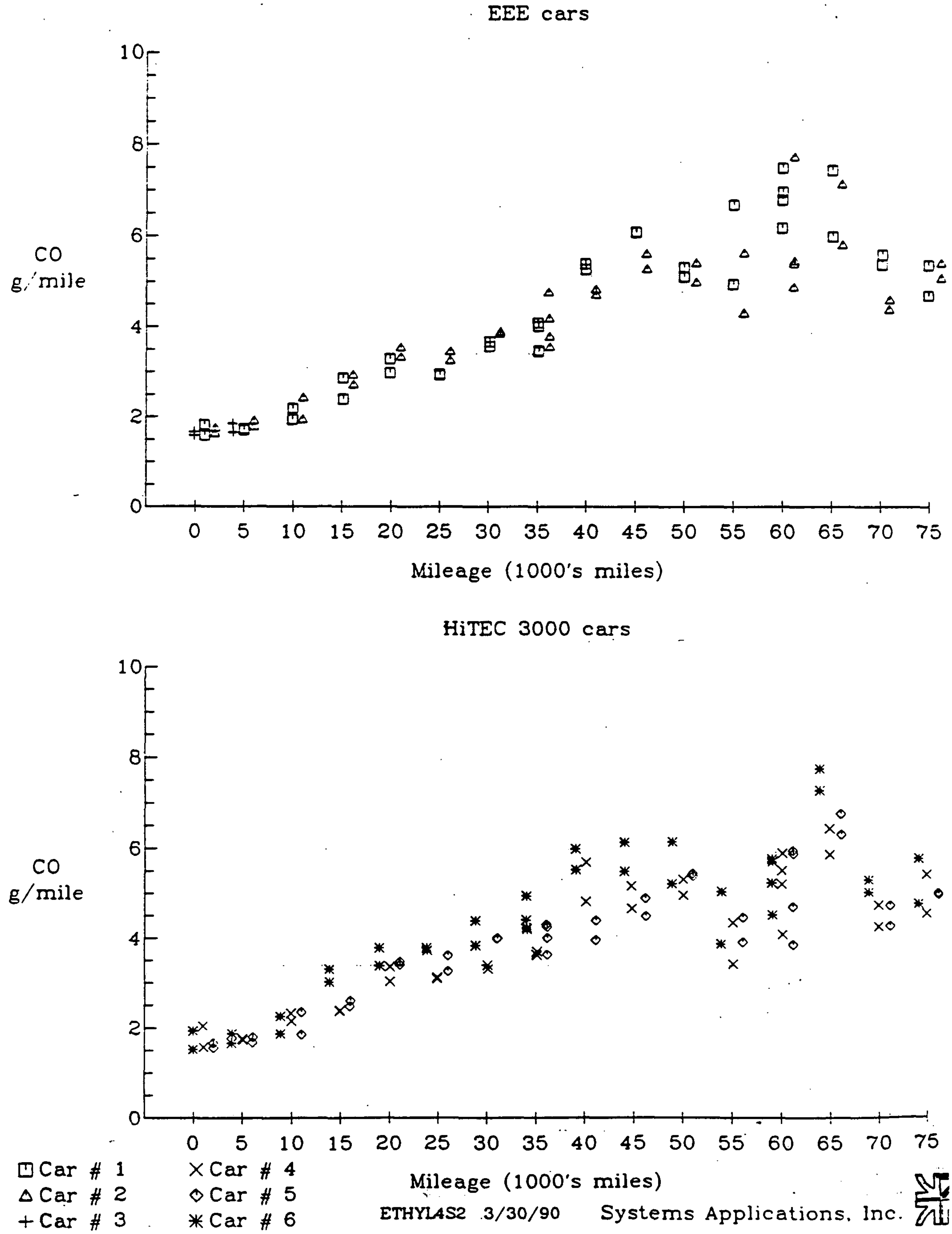
Tailpipe Nitrogen Oxides Emissions for Model Group I





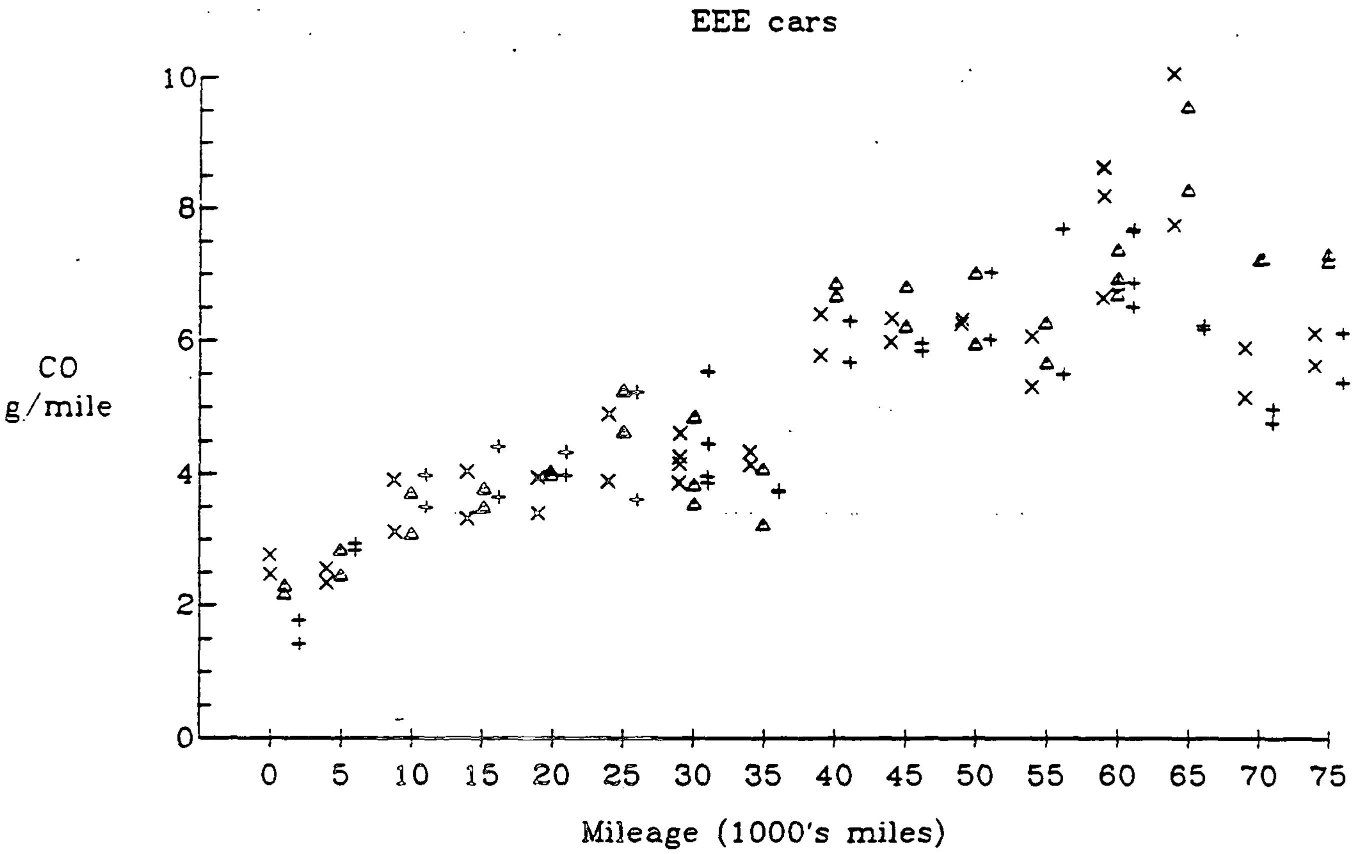
ETHYL4S2 3/30/90 Systems Applications, Inc.

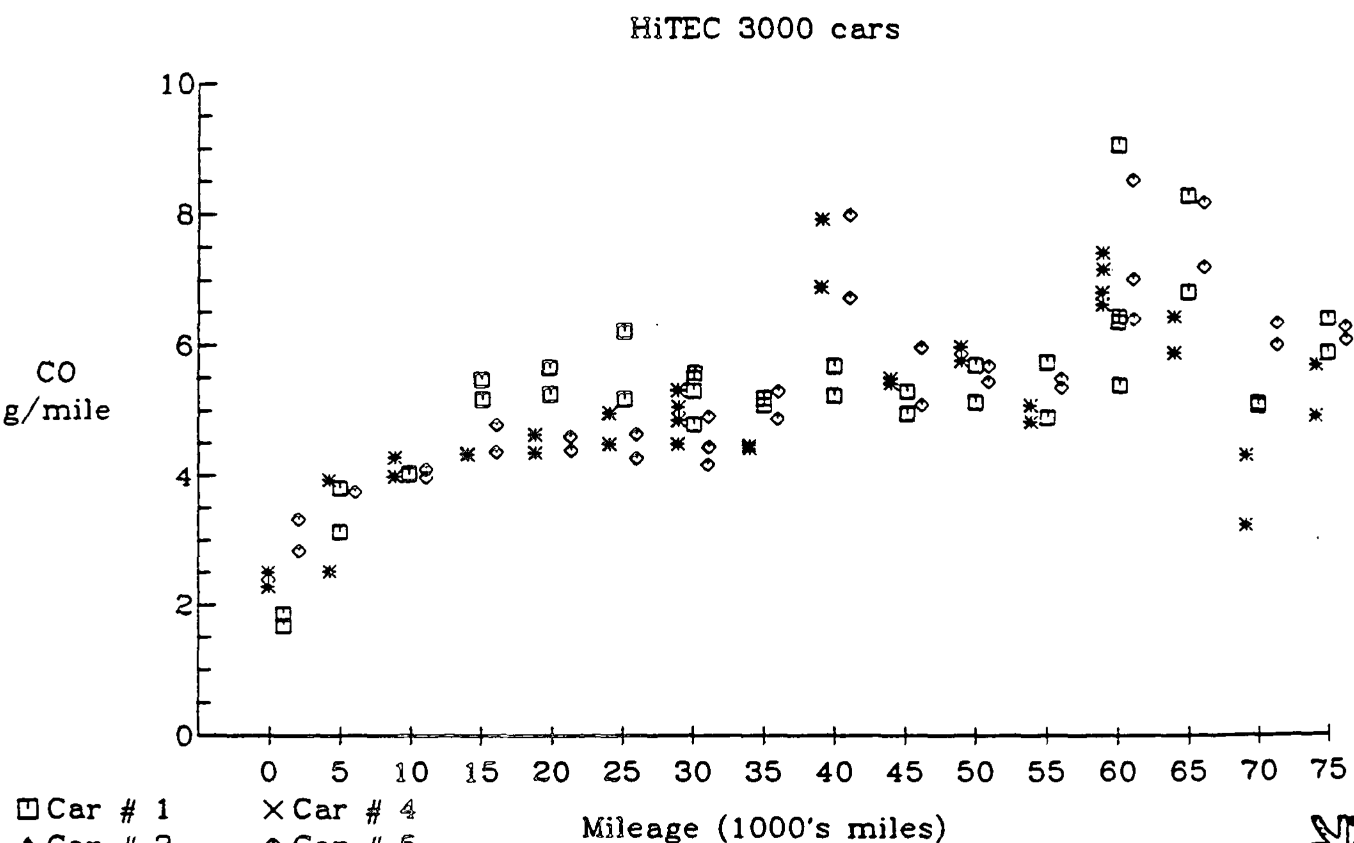
Tailpipe Carbon Monoxide Emissions for Model Group D



ETHYL4S2 3/30/90 Systems Applications, Inc.

Tailpipe Carbon Monoxide Emissions for Model Group E



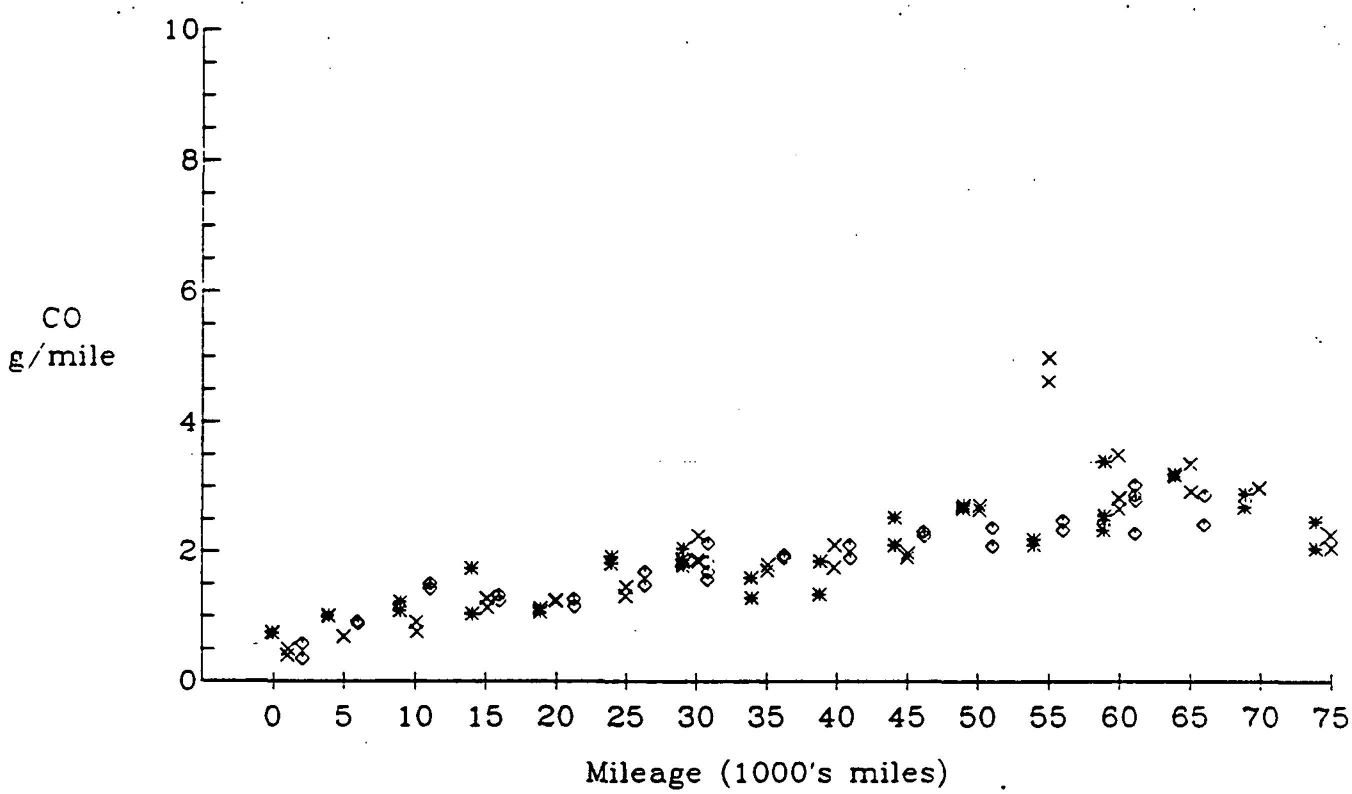


□ Car # 1 × Car # 4
△ Car # 2 ◇ Car # 5
+ Car # 3 ✳ Car # 6

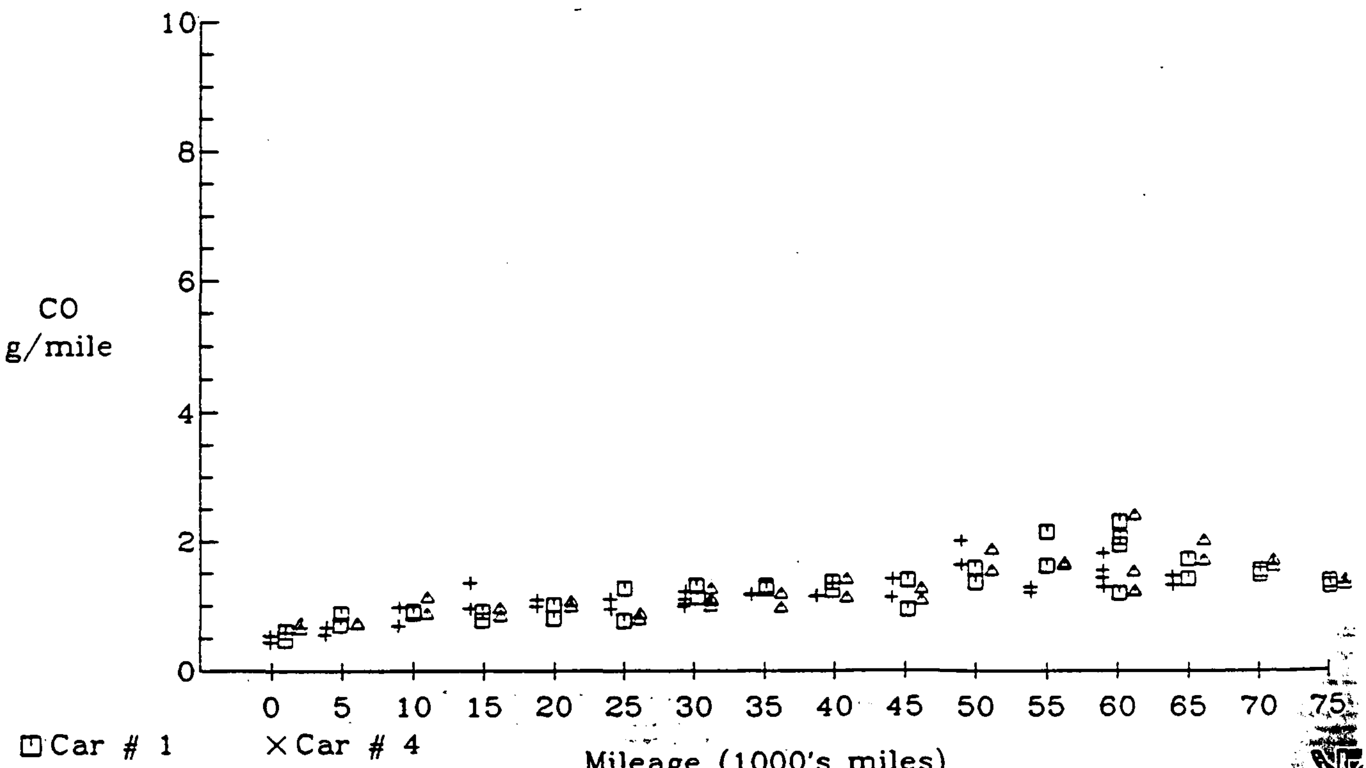
ETHYL4S2 3/30/90 Systems Applications, Inc.

Tailpipe Carbon Monoxide Emissions for Model Group F

EEE cars



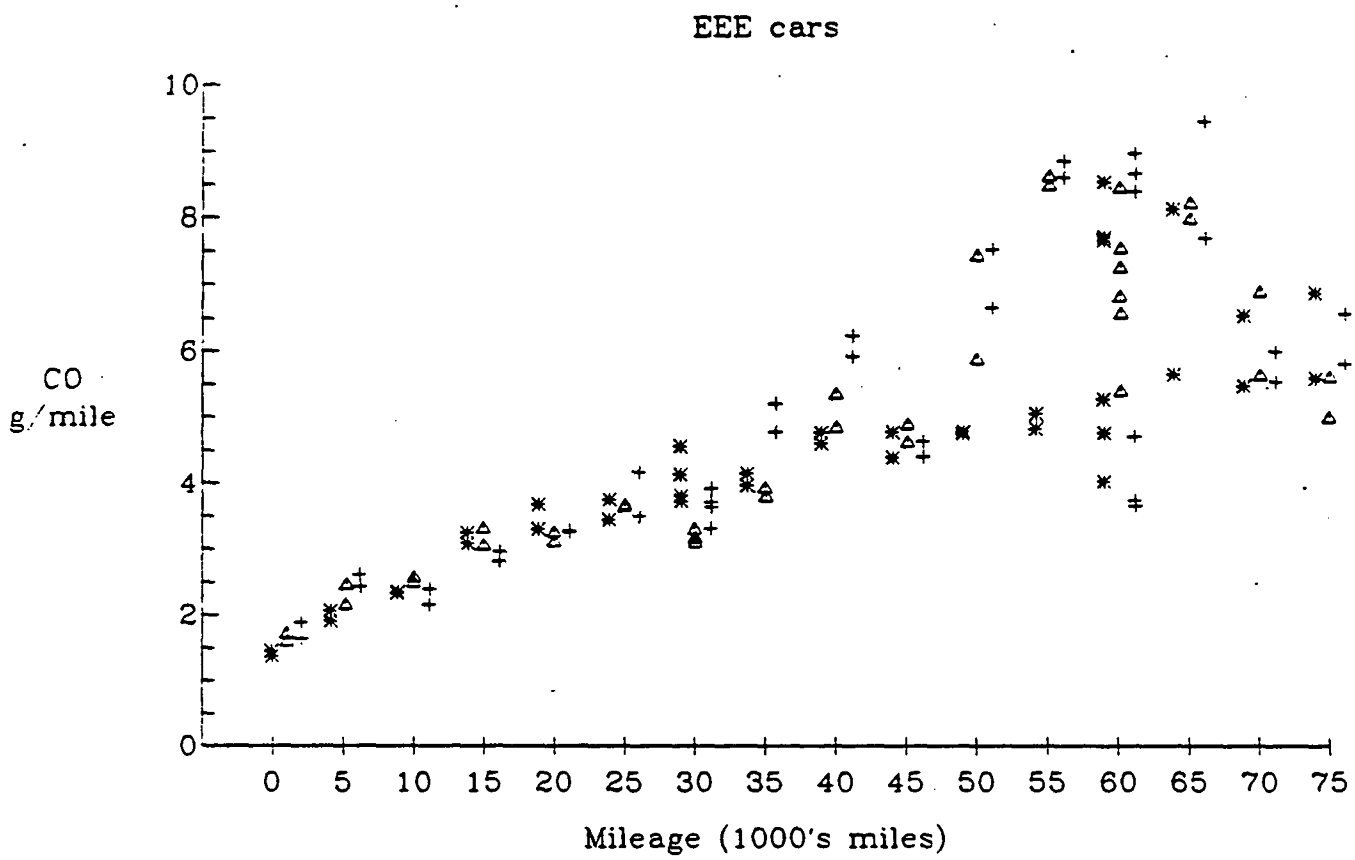
HiTEC 3000 cars

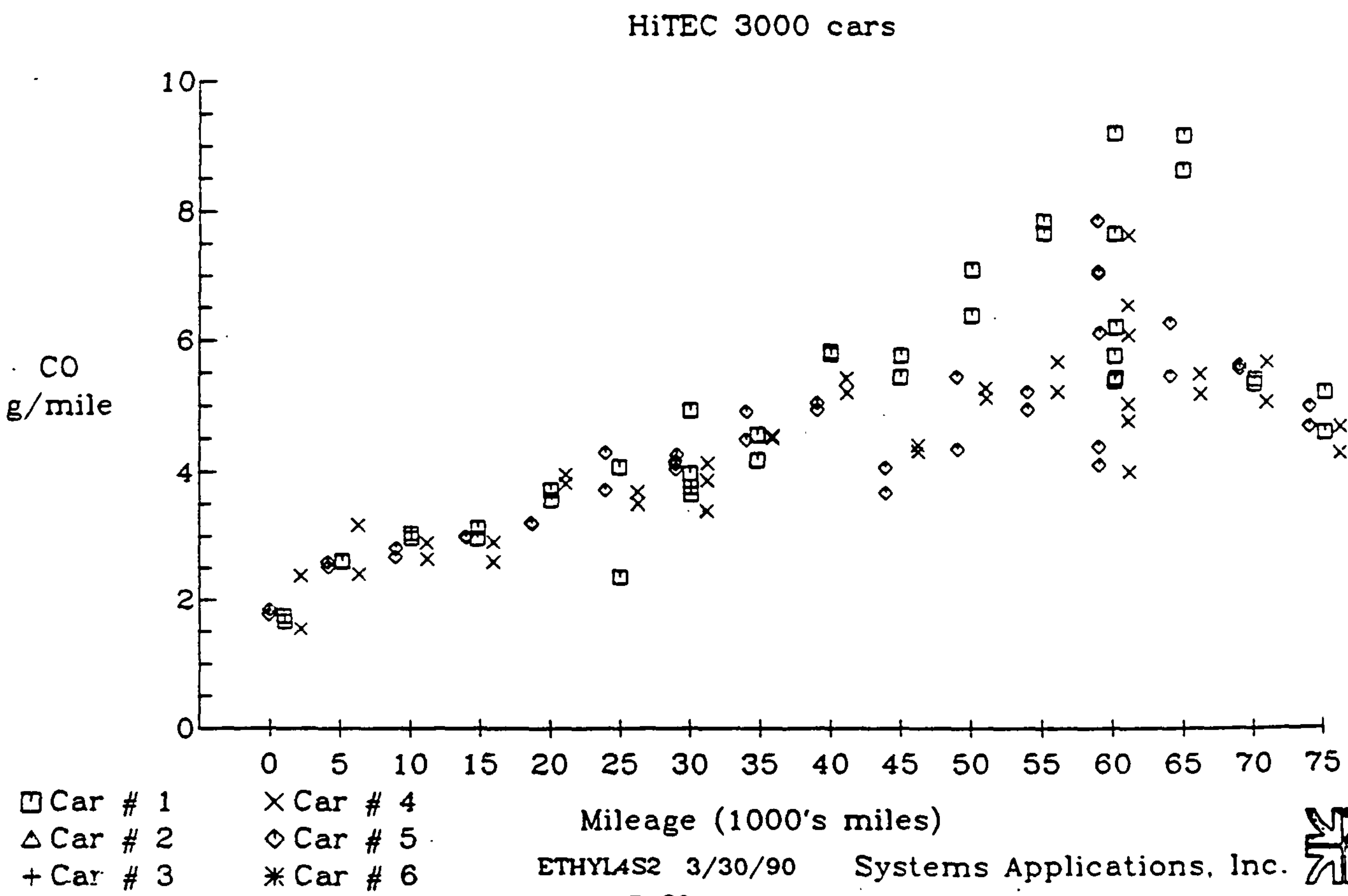


□ Car # 1
△ Car # 2
+ Car # 3
× Car # 4
◇ Car # 5
✳ Car # 6

ETHYL4S2 3/30/90 Systems Applications, Inc.

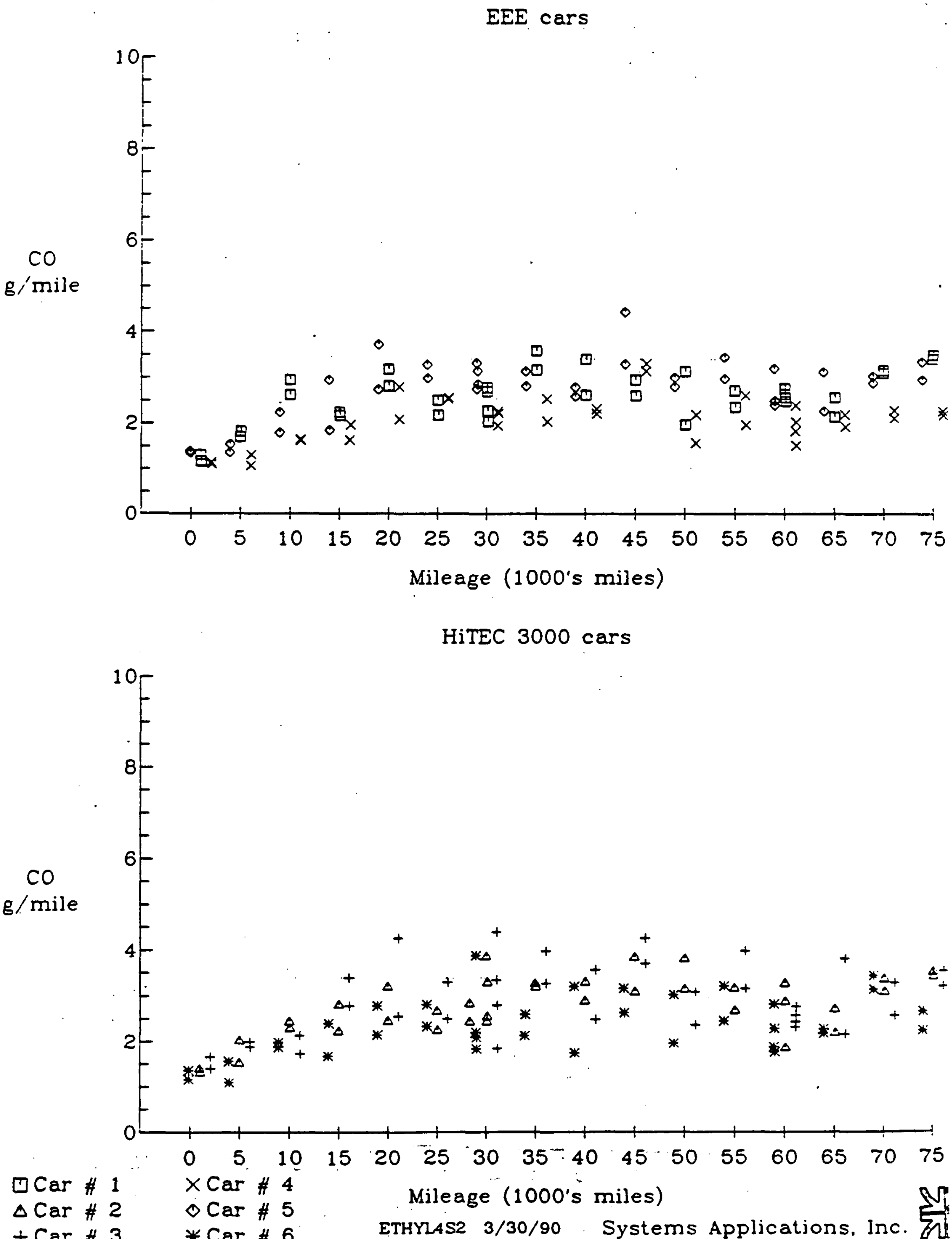
Tailpipe Carbon Monoxide Emissions for Model Group T





ETHYL4S2 3/30/90 Systems Applications, Inc.

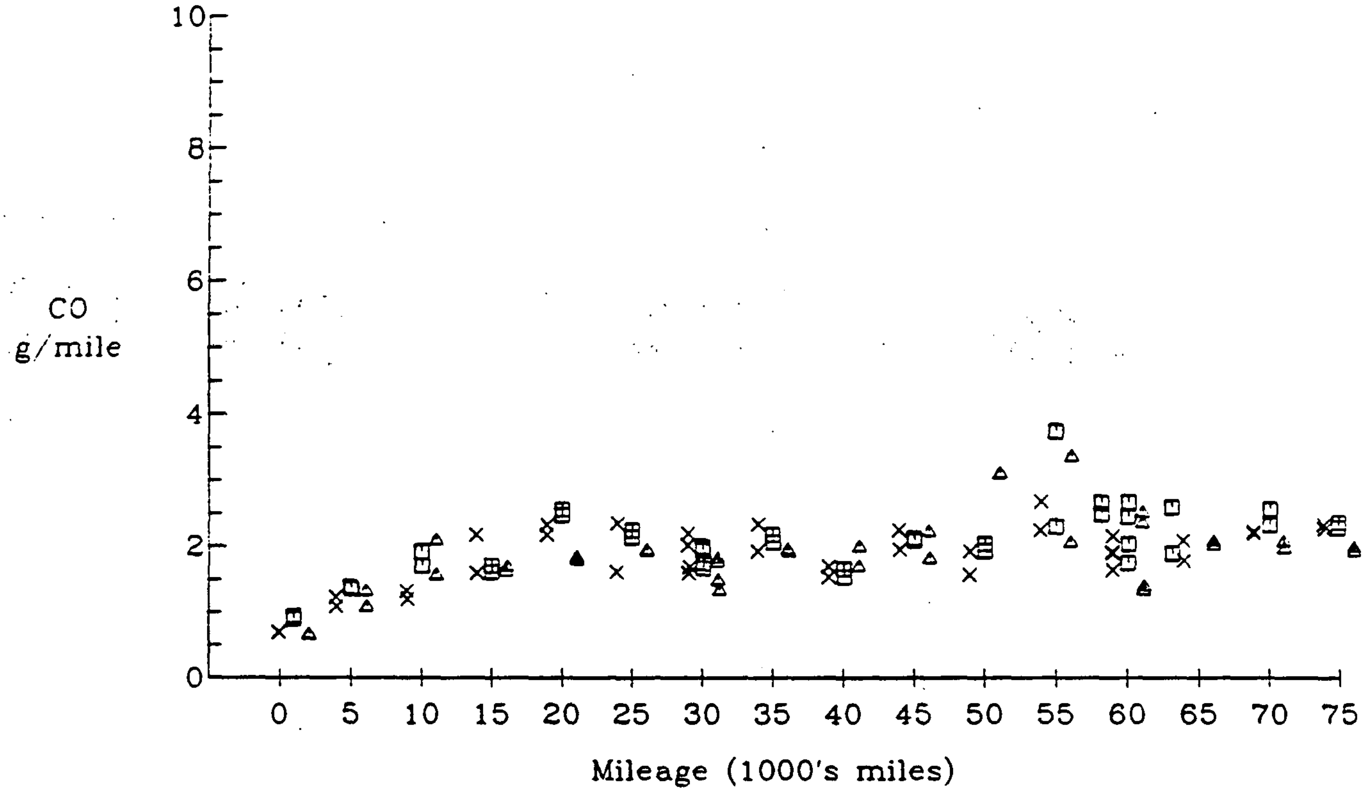
Tailpipe Carbon Monoxide Emissions for Model Group C



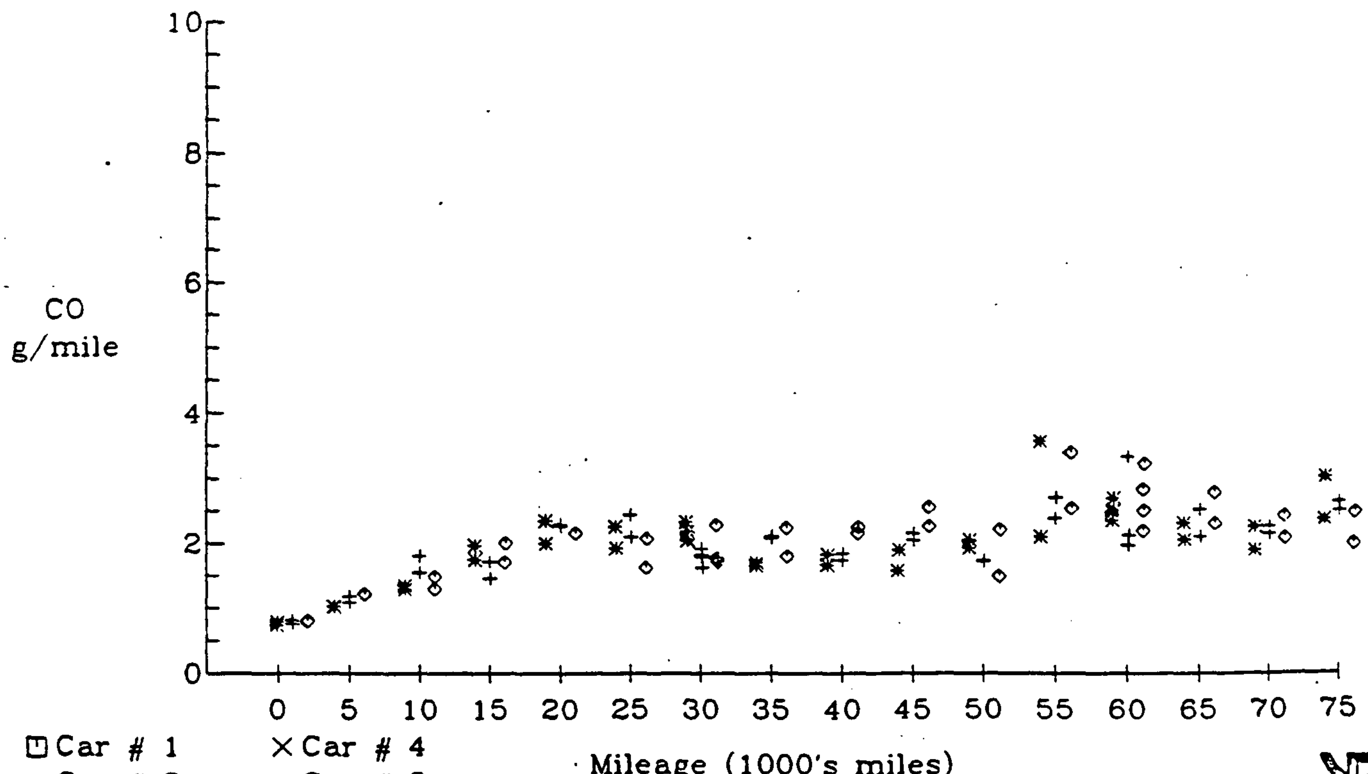
ETHYL4S2 3/30/90 Systems Applications, Inc.

Tailpipe Carbon Monoxide Emissions for Model Group G

EEE cars



HiTEC 3000 cars

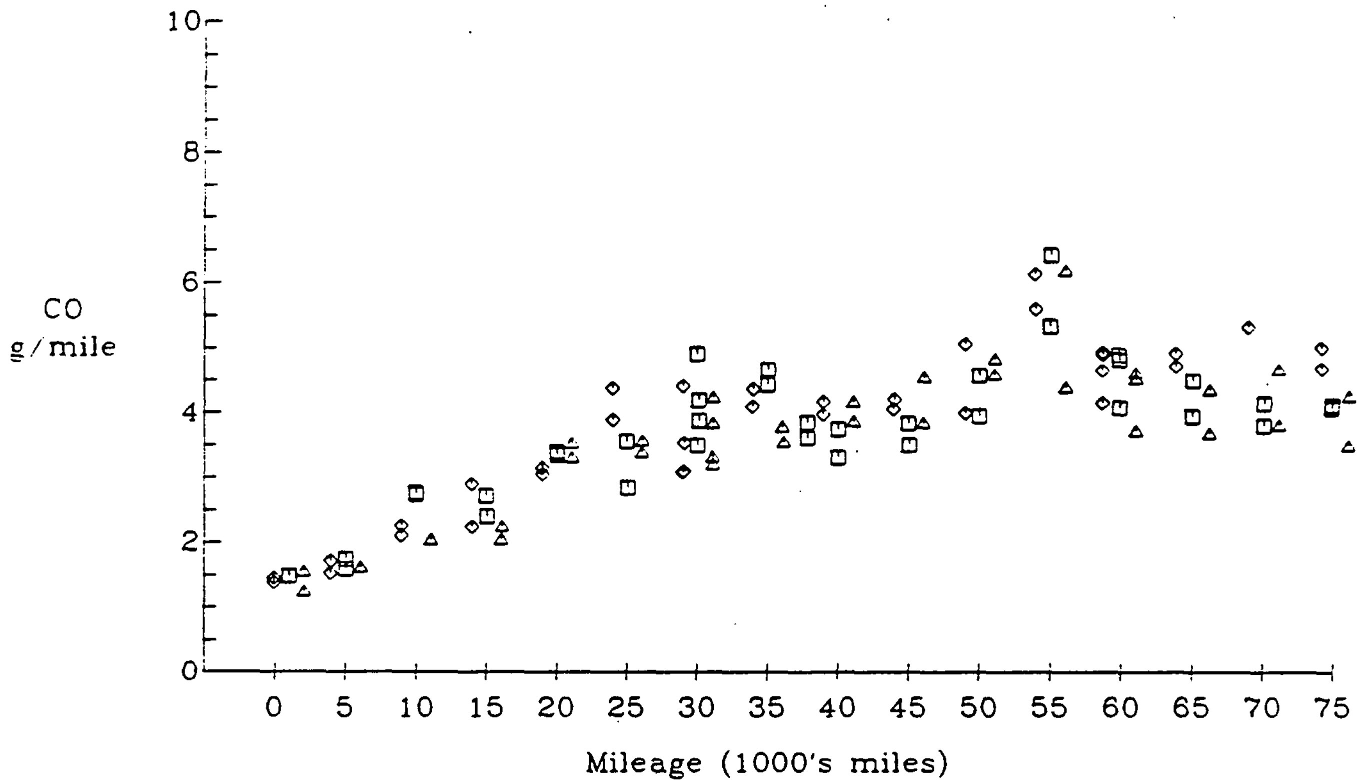


□ Car # 1 × Car # 4
△ Car # 2 ◇ Car # 5
+ Car # 3 ✳ Car # 6

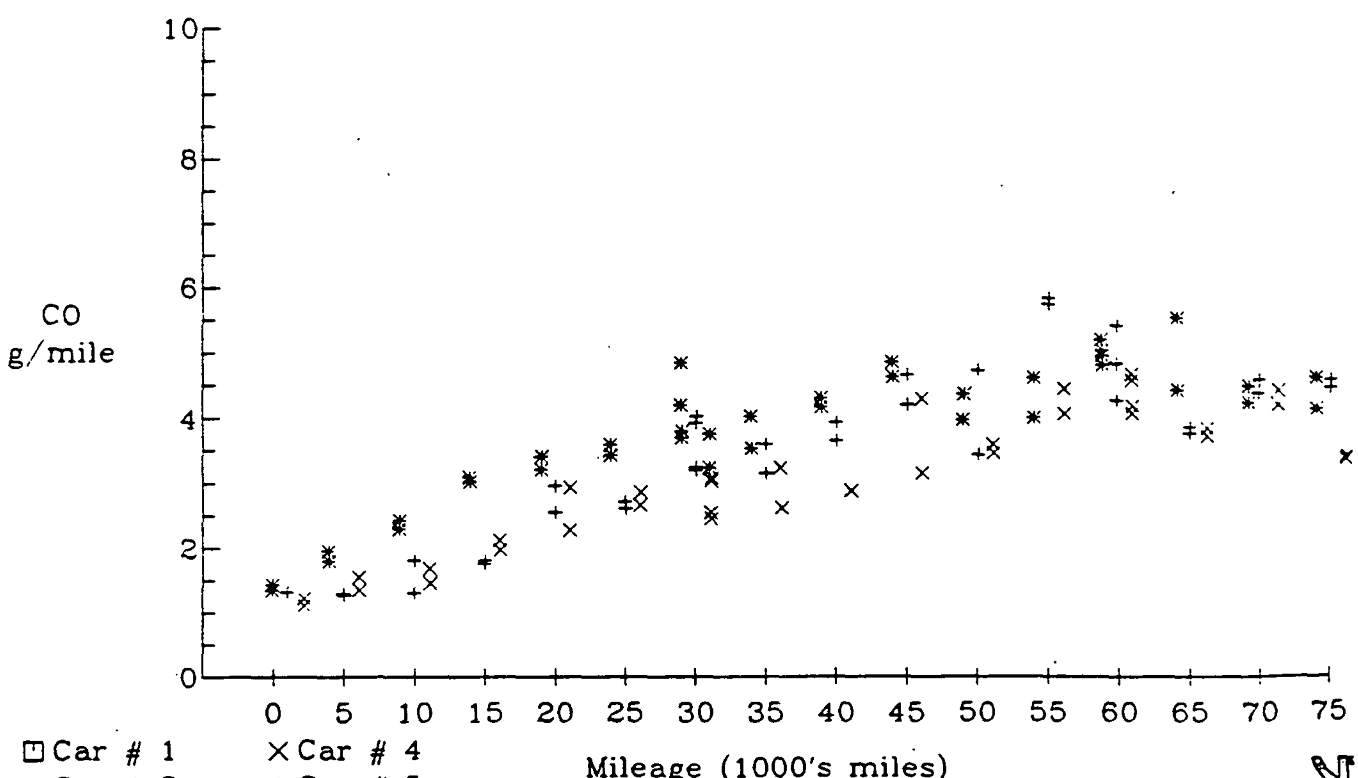
ETHYL4S2 3/30/90 Systems Applications, Inc.

Tailpipe Carbon Monoxide Emissions for Model Group H

EEE cars



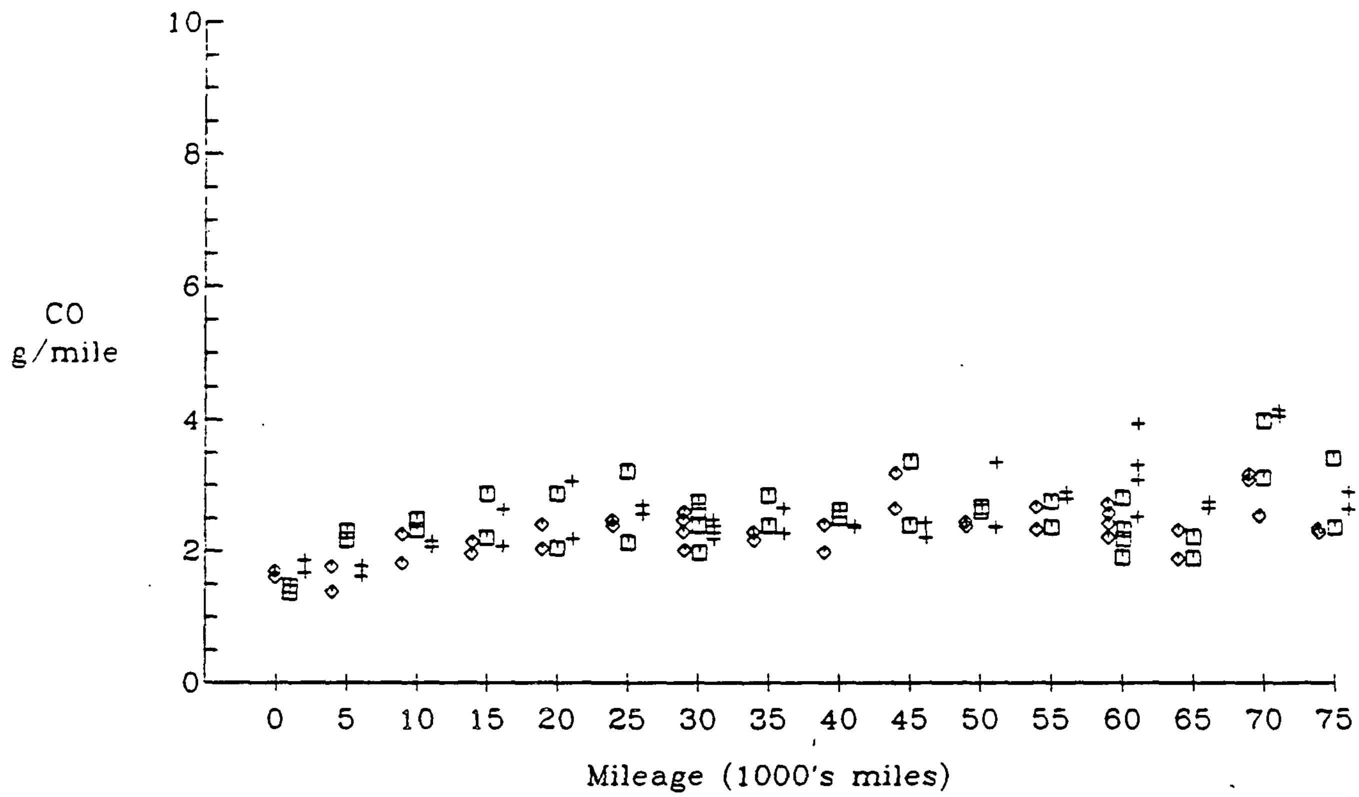
HiTEC 3000 cars



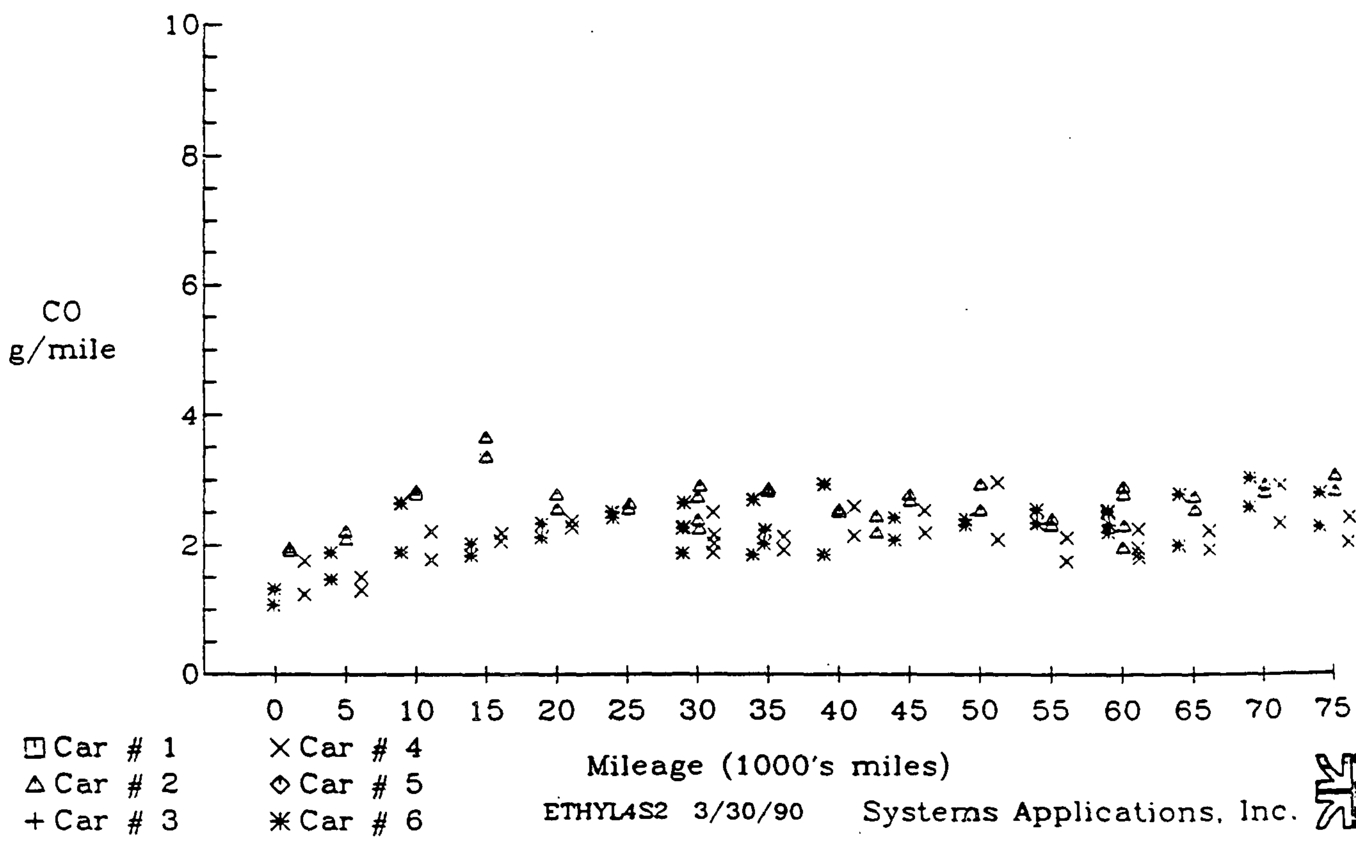
ETHYL4S2 3/30/90 Systems Applications, Inc.

Tailpipe Carbon Monoxide Emissions for Model Group I

EEE cars

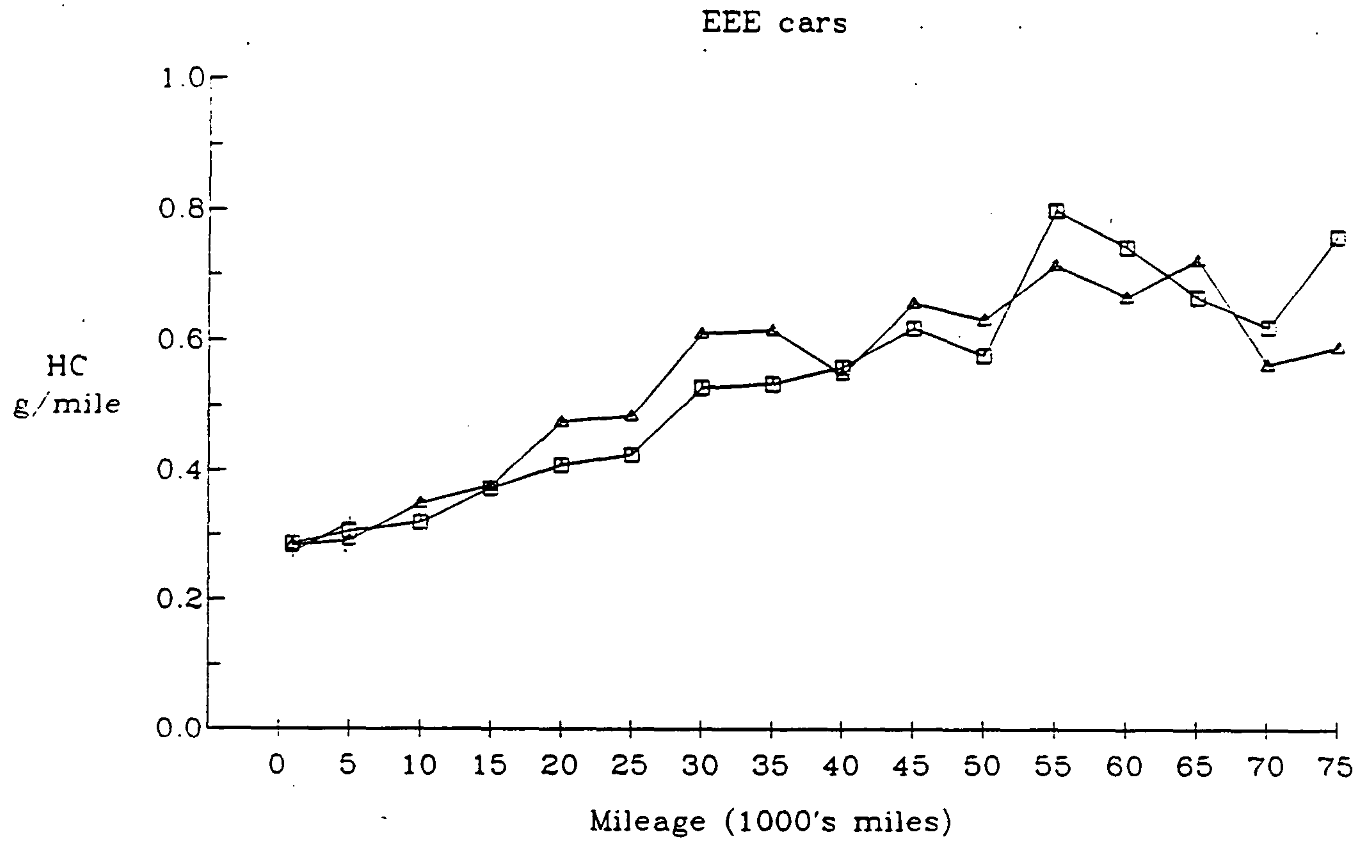


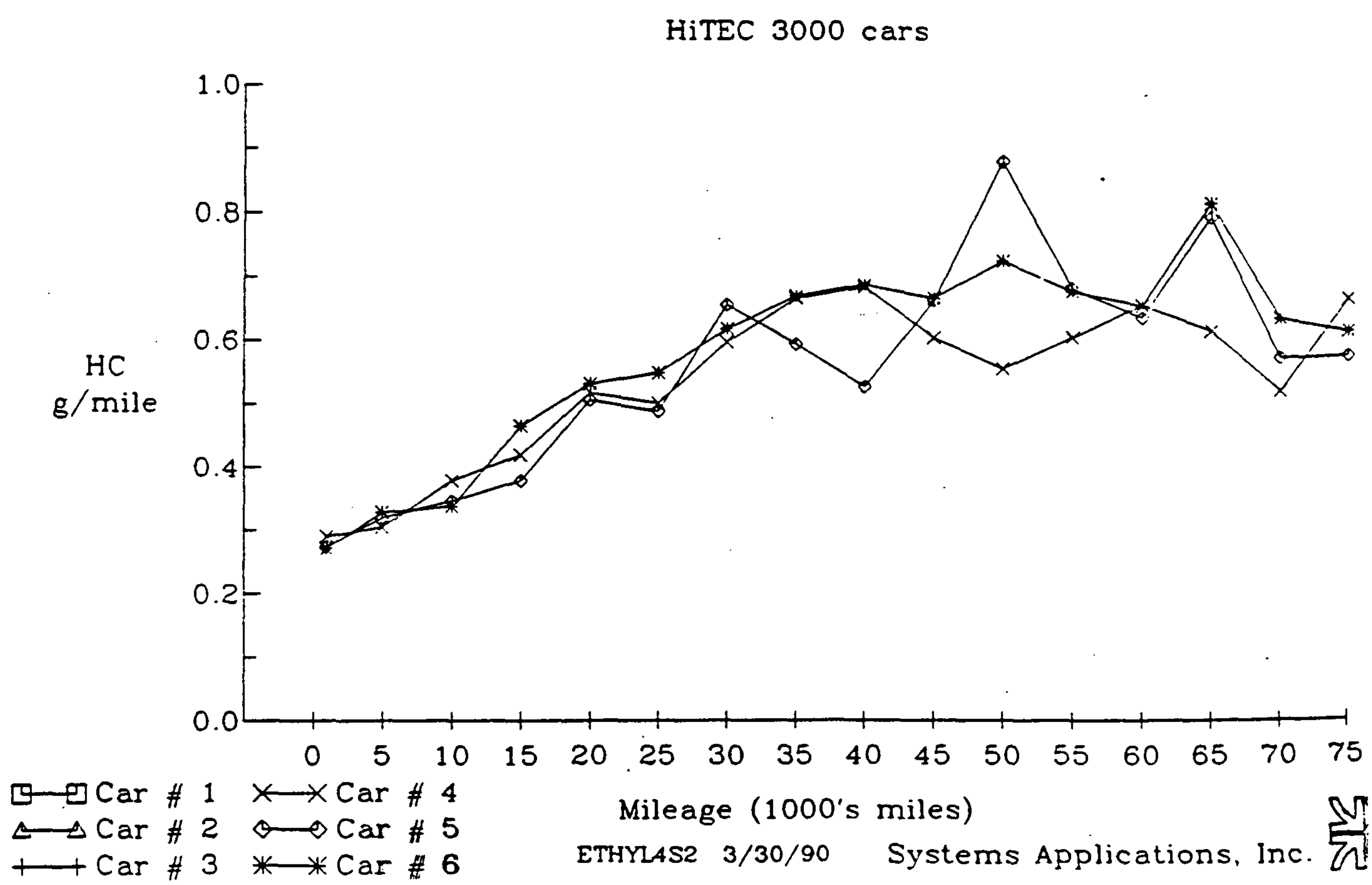
HiTEC 3000 cars



ETHYL4S2 3/30/90 Systems Applications, Inc.

Average Tailpipe Hydrocarbon Emissions
for Model Group D

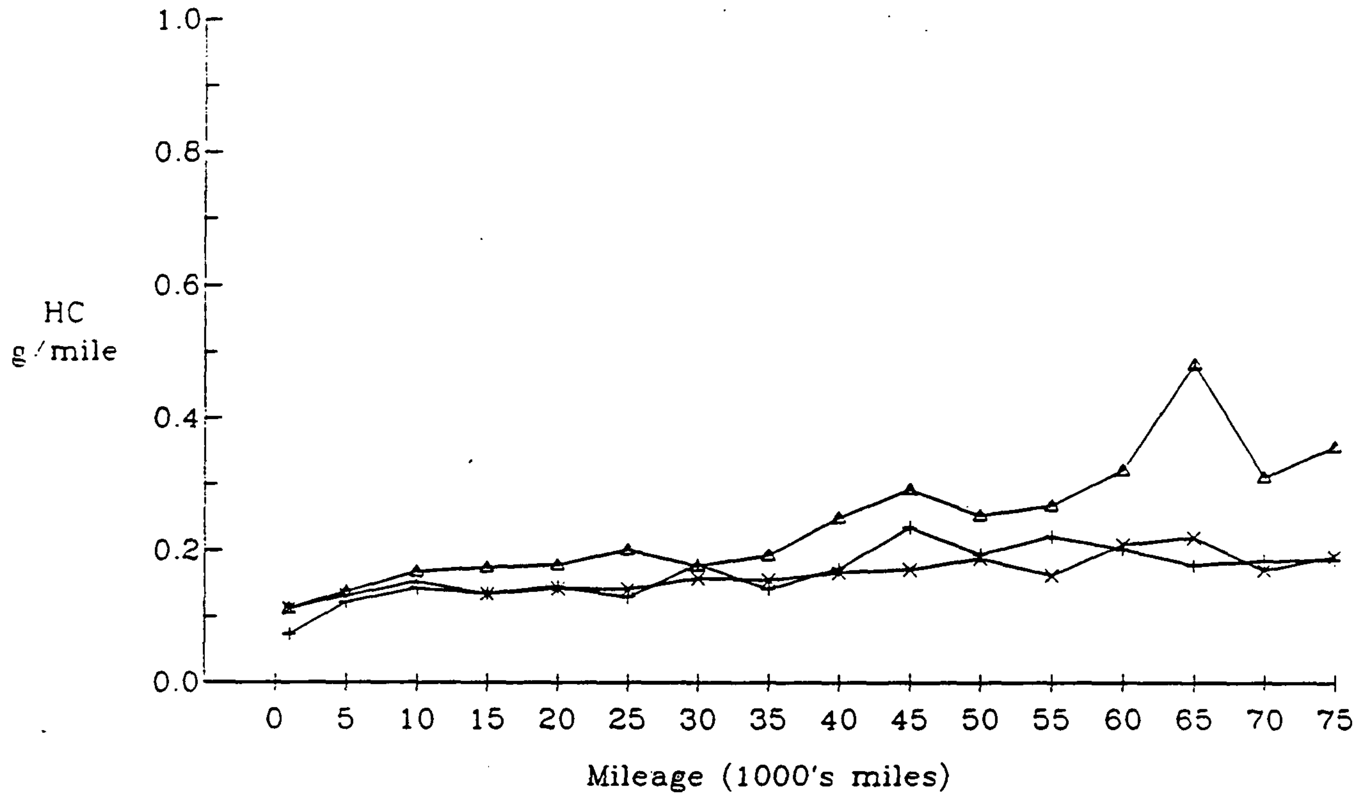




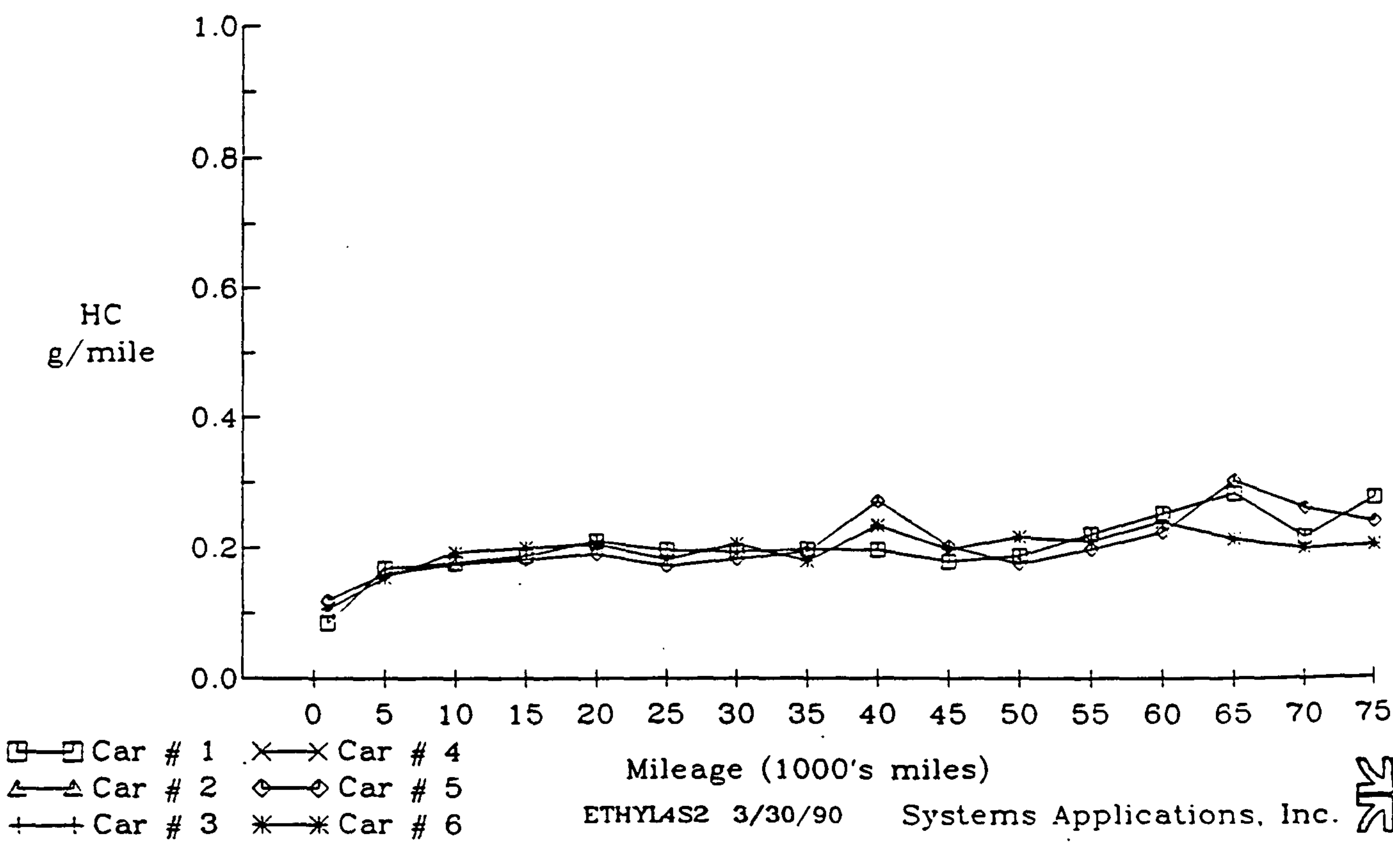
ETHYL4S2 3/30/90 Systems Applications, Inc.

Average Tailpipe Hydrocarbon Emissions for Model Group E

EEE cars

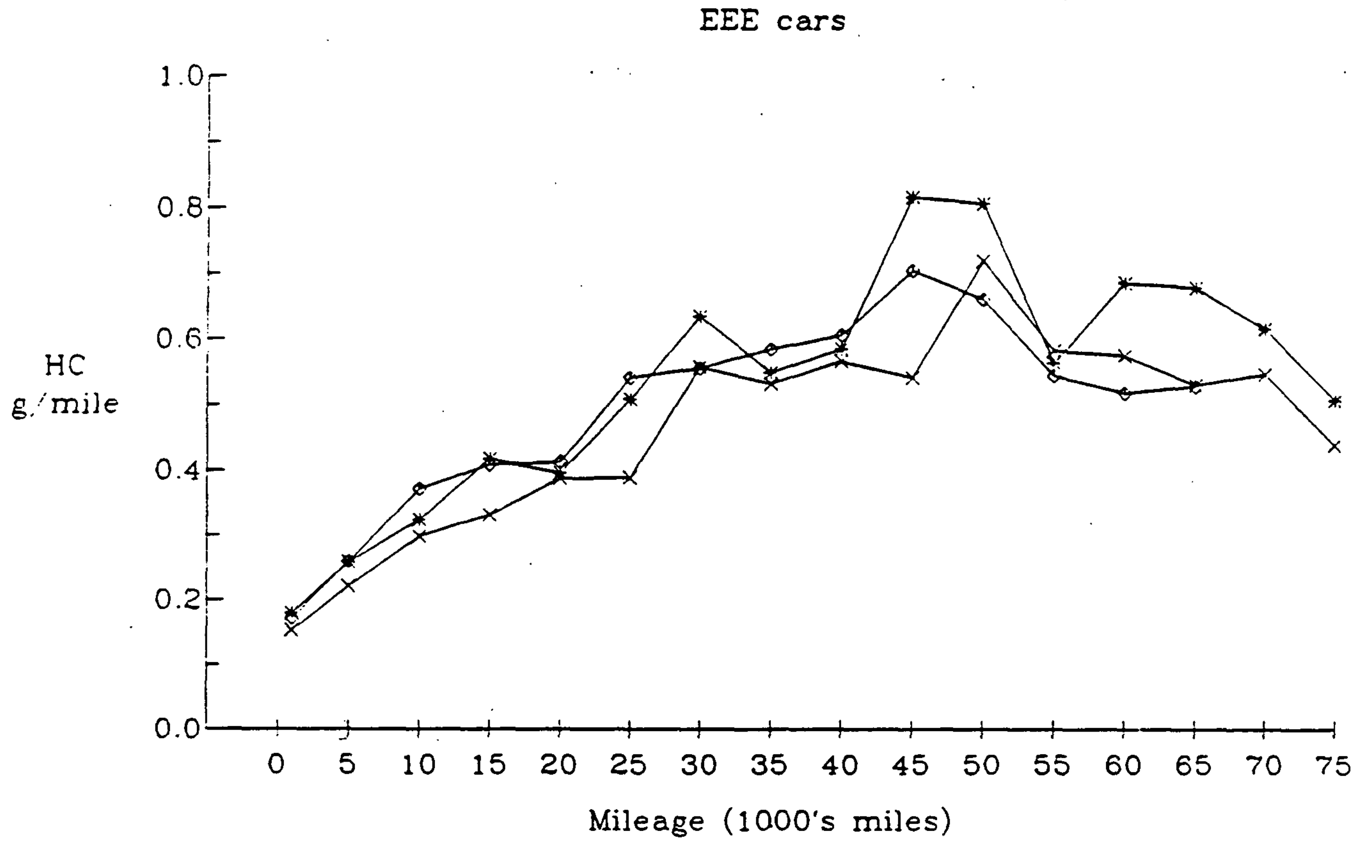


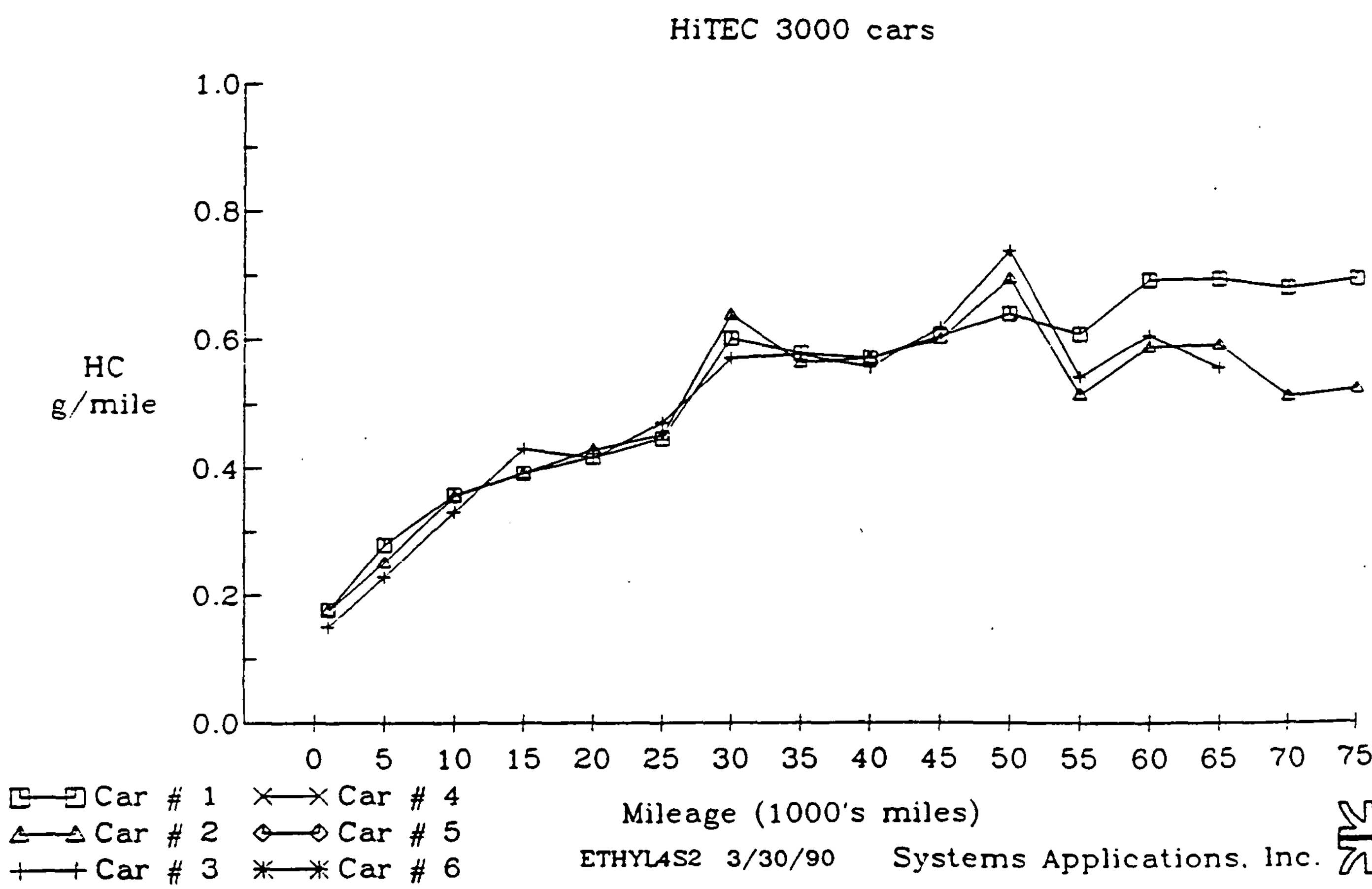
HiTEC 3000 cars



ETHYL4S2 3/30/90 Systems Applications, Inc.

Average Tailpipe Hydrocarbon Emissions for Model Group F

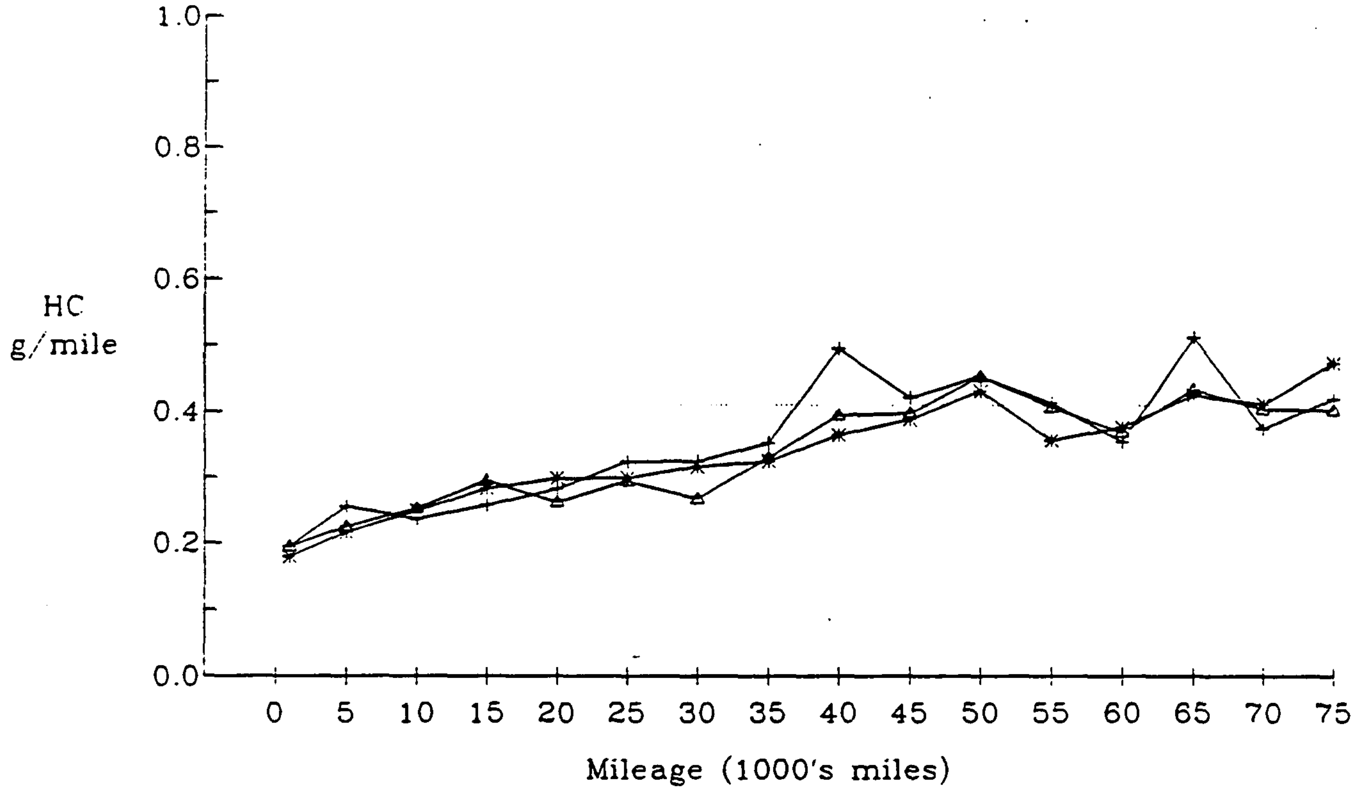




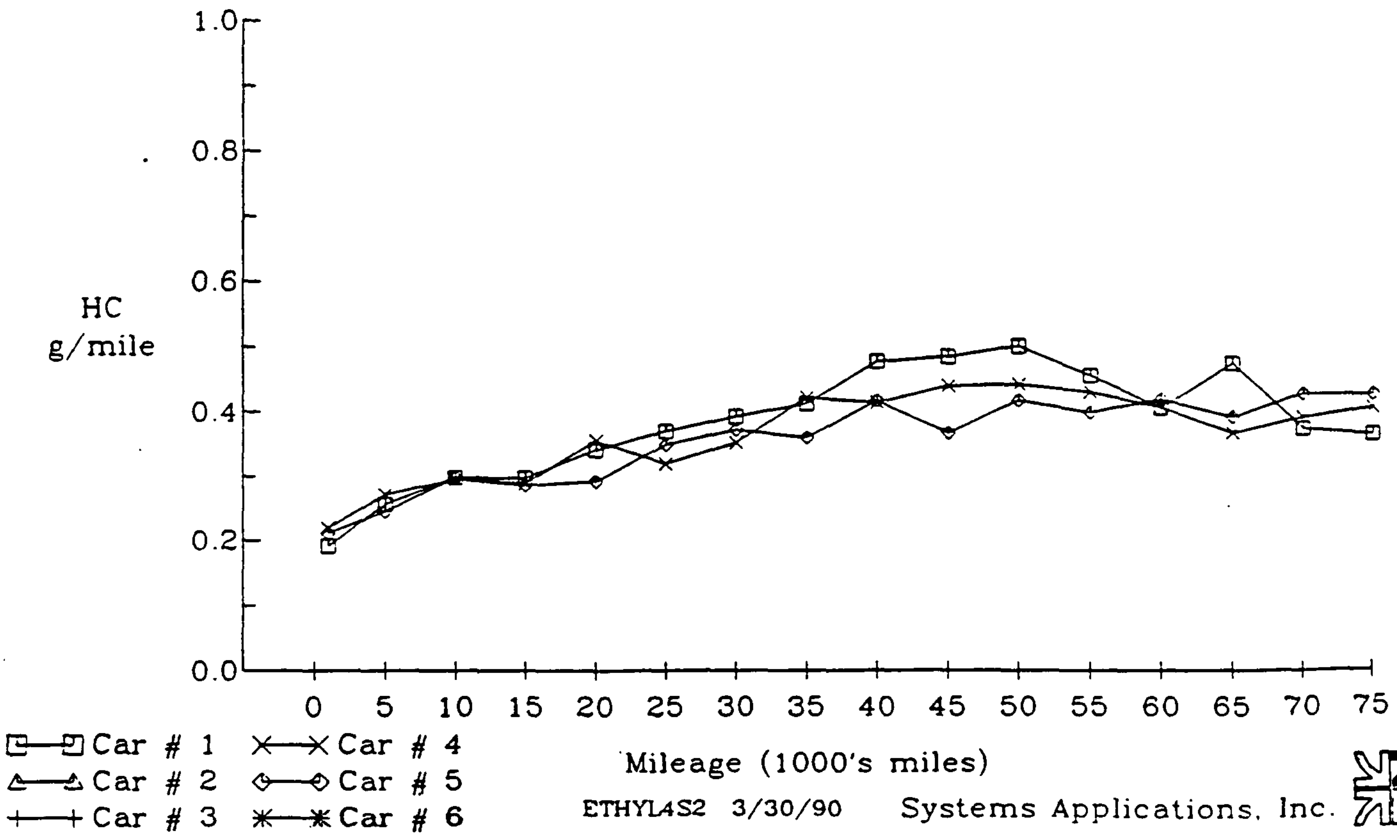
ETHYL4S2 3/30/90 Systems Applications, Inc.

Average Tailpipe Hydrocarbon Emissions for Model Group T

EEE cars

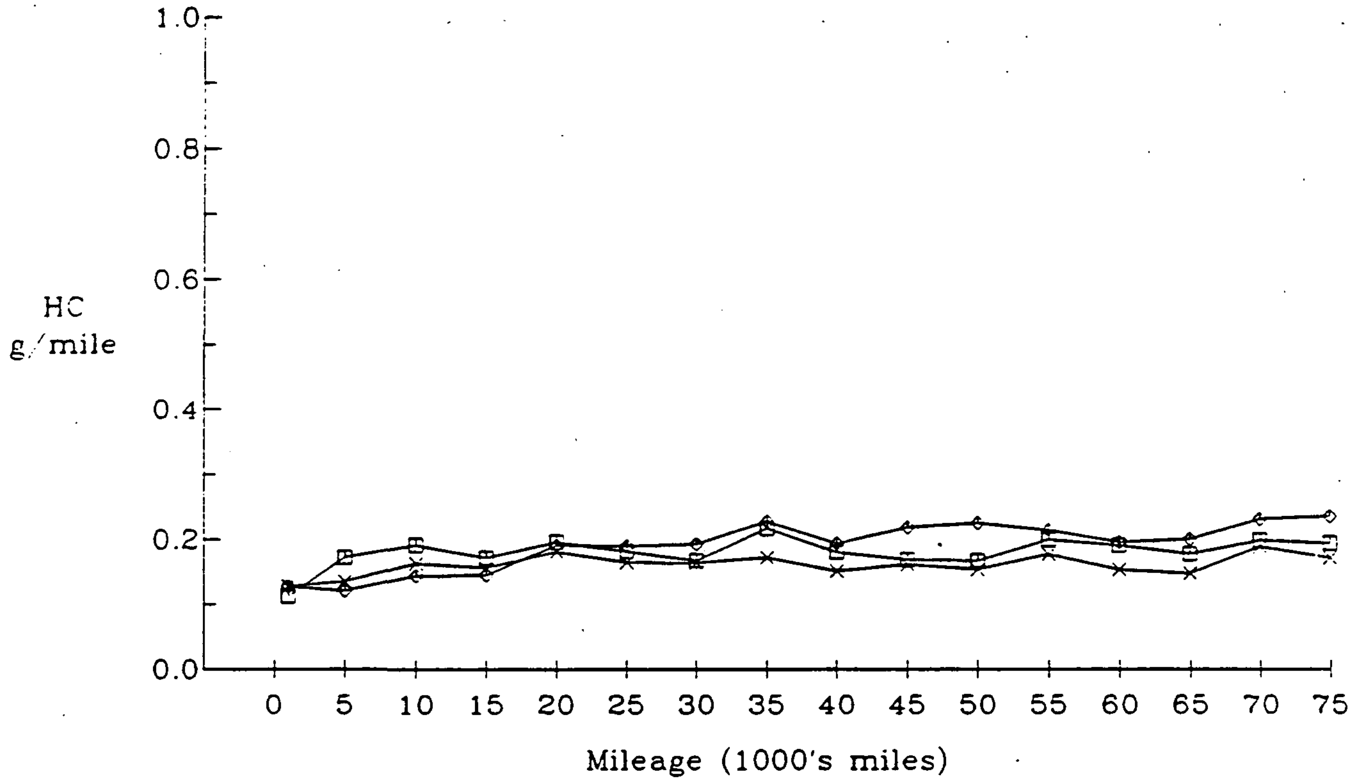


HiTEC 3000 cars

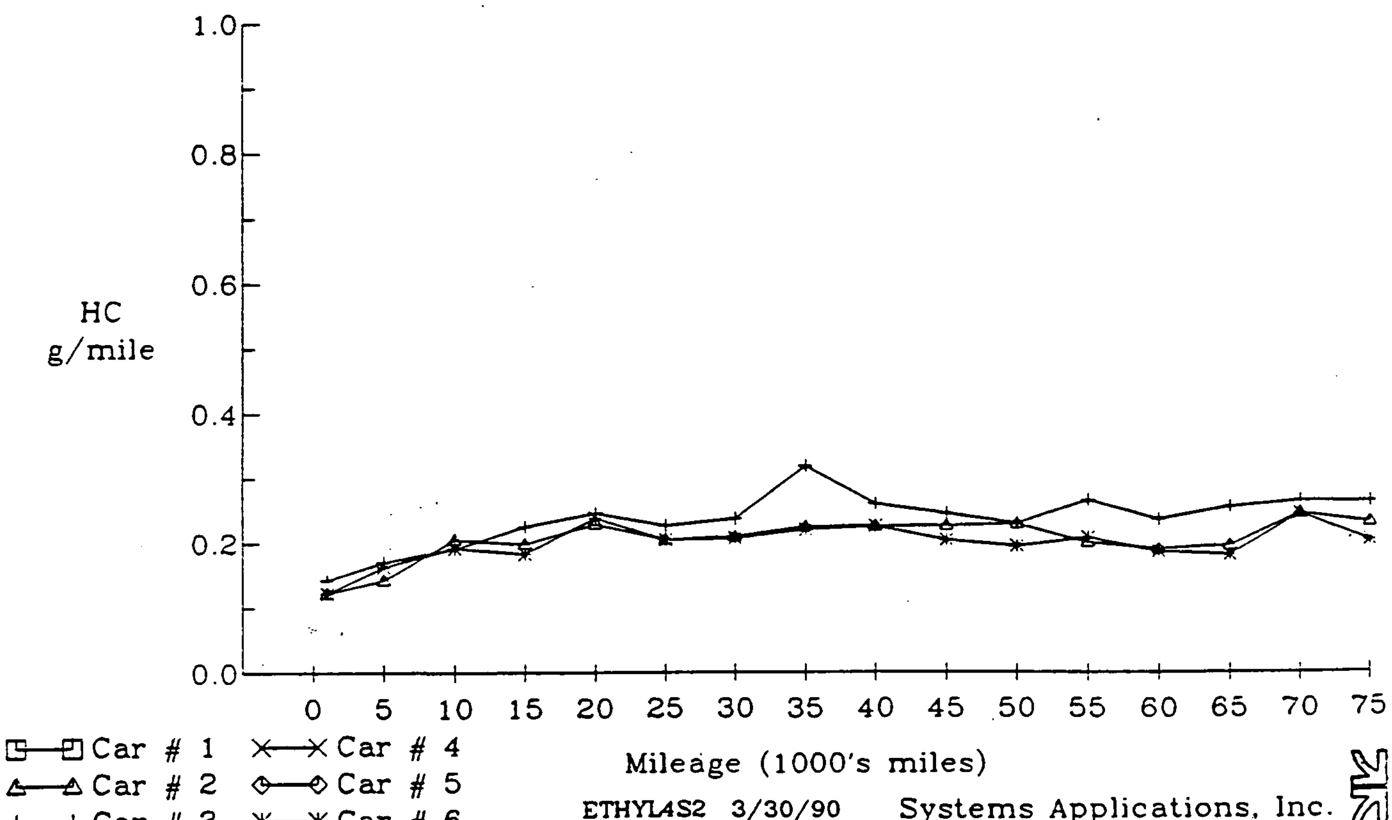


Average Tailpipe Hydrocarbon Emissions for Model Group C

EEE cars



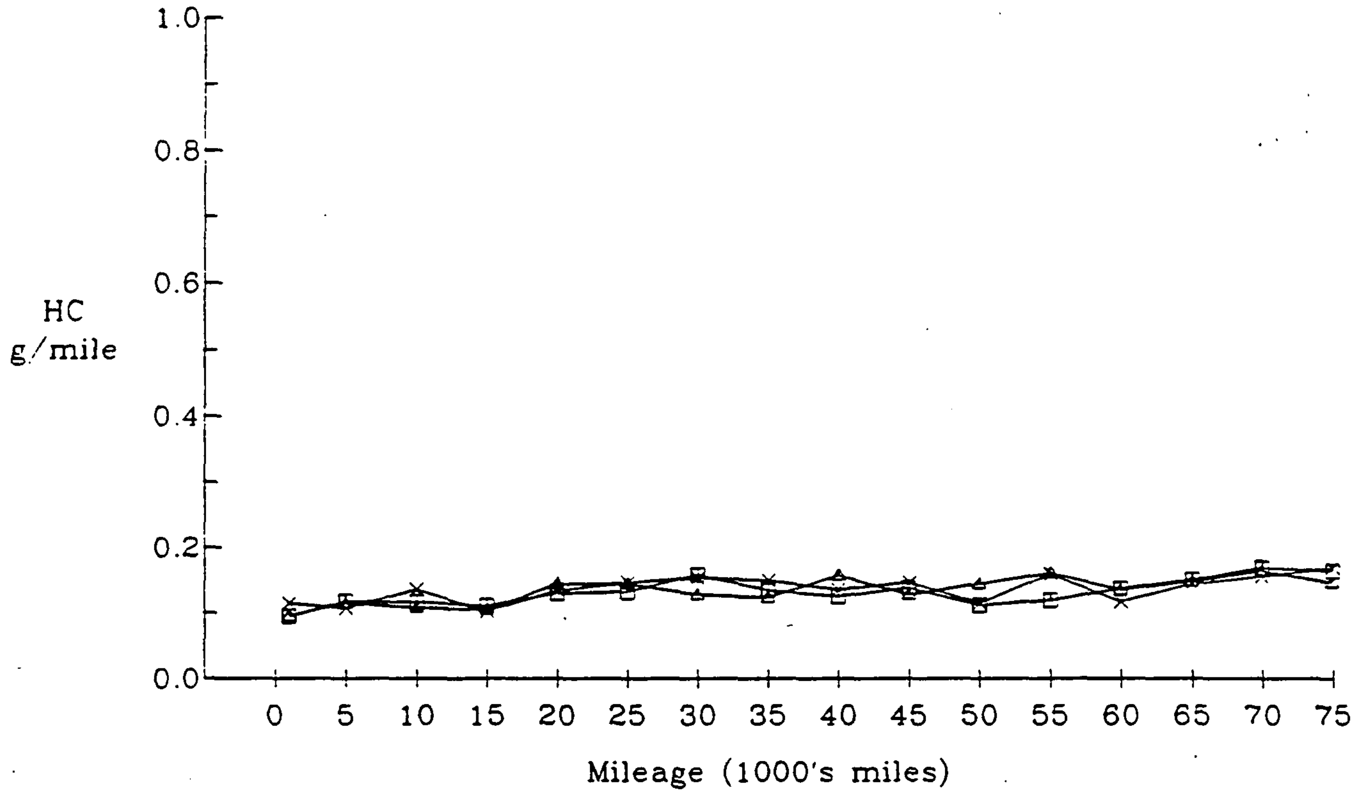
HiTEC 3000 cars



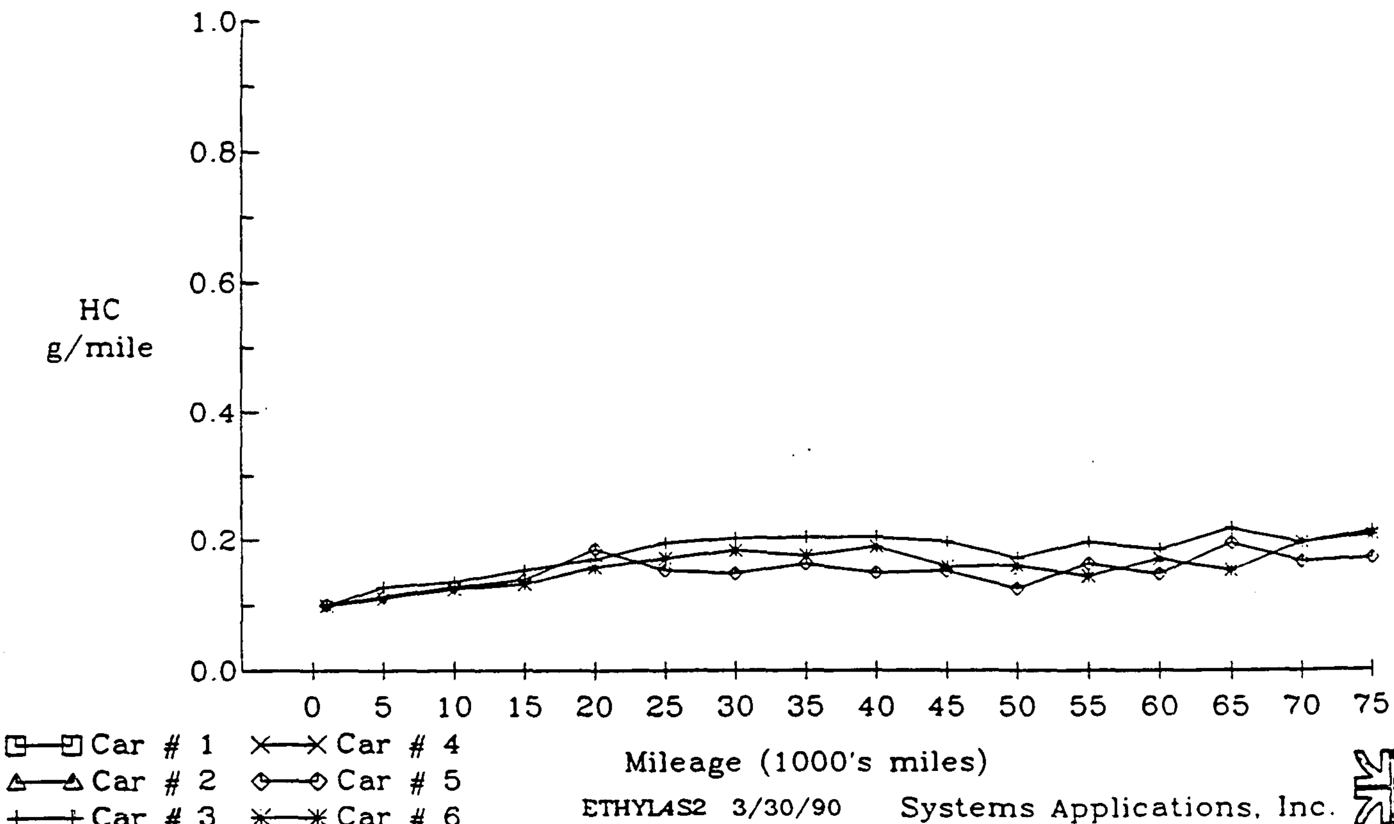
ETHYL4S2 3/30/90 Systems Applications, Inc.

Average Tailpipe Hydrocarbon Emissions for Model Group G

EEE cars



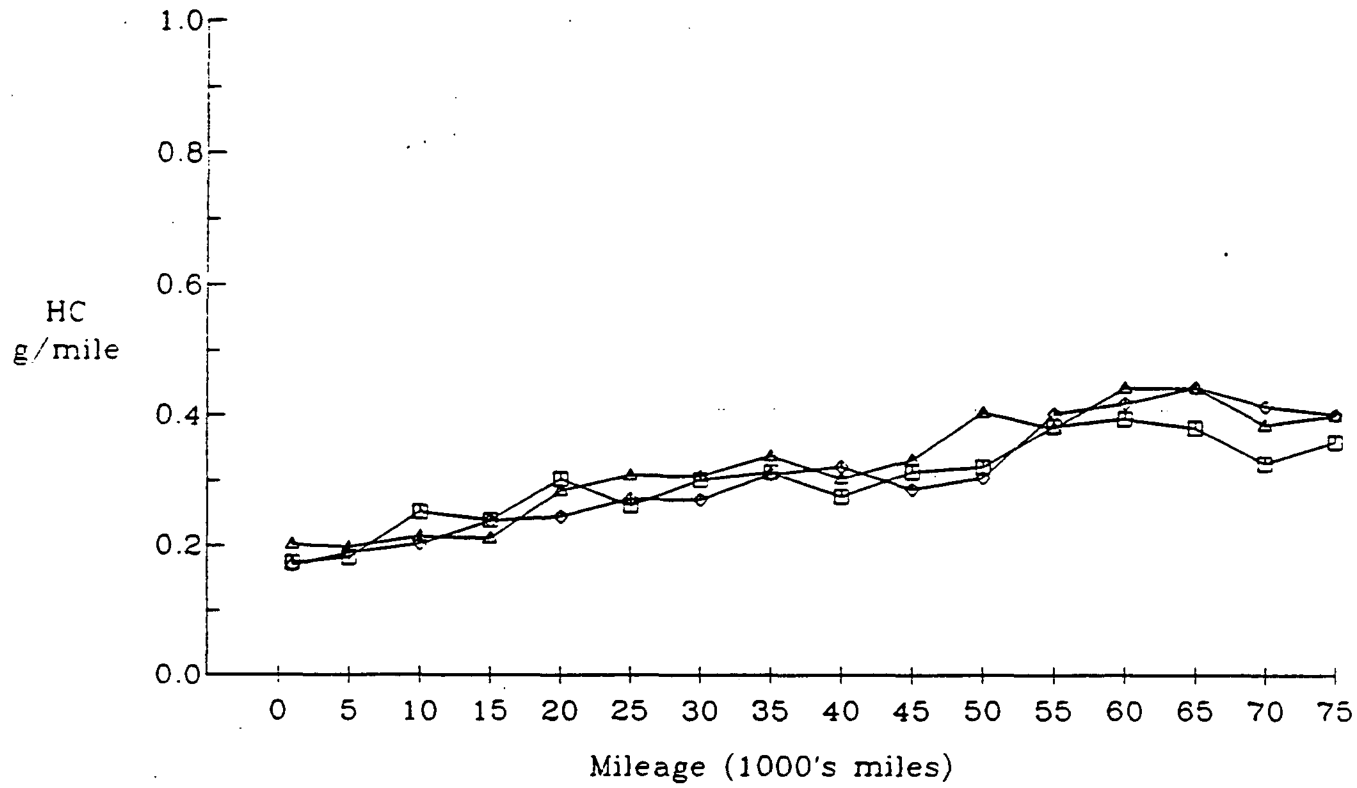
HiTEC 3000 cars



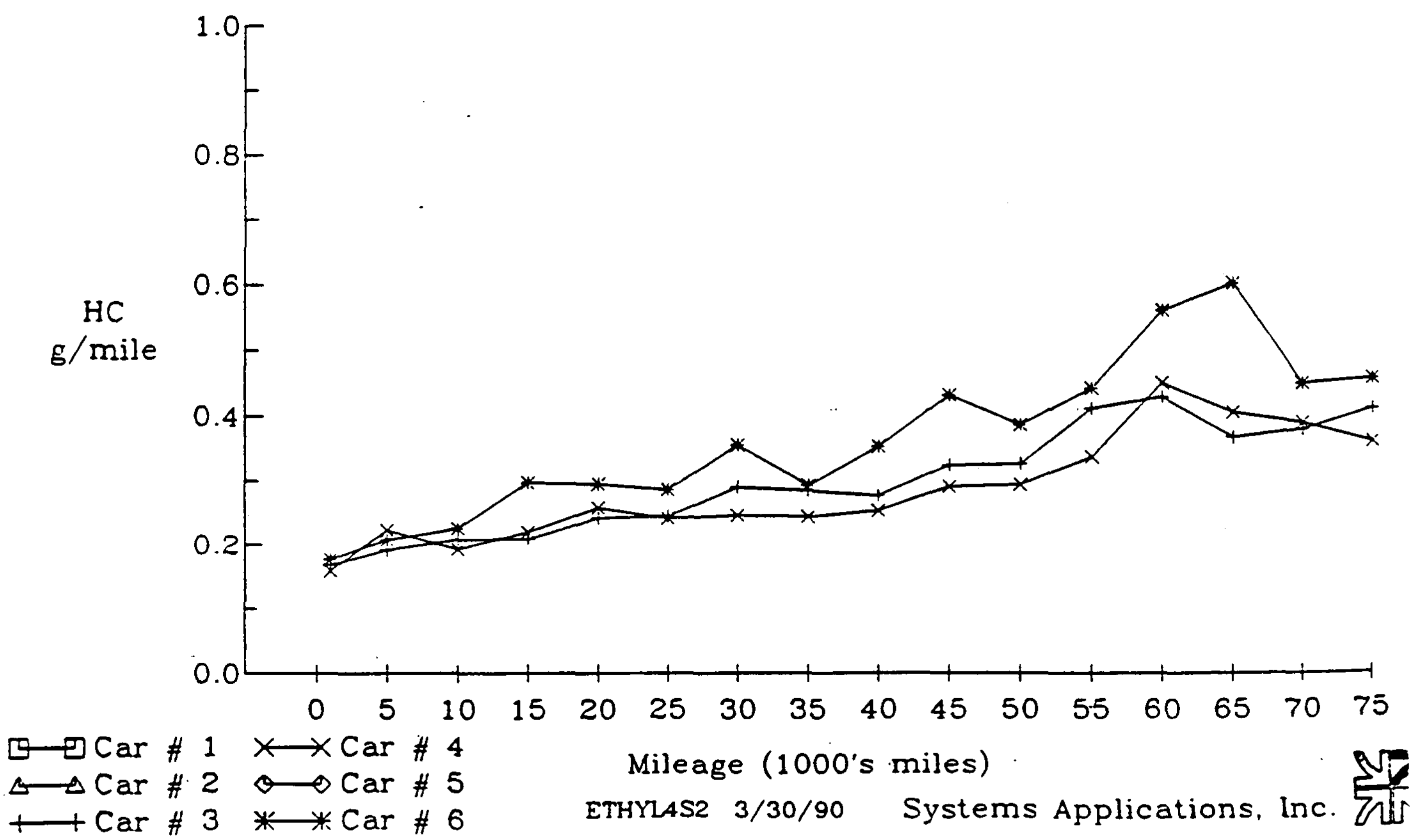
ETHYL4S2 3/30/90 Systems Applications, Inc.

Average Tailpipe Hydrocarbon Emissions for Model Group H

EEE cars



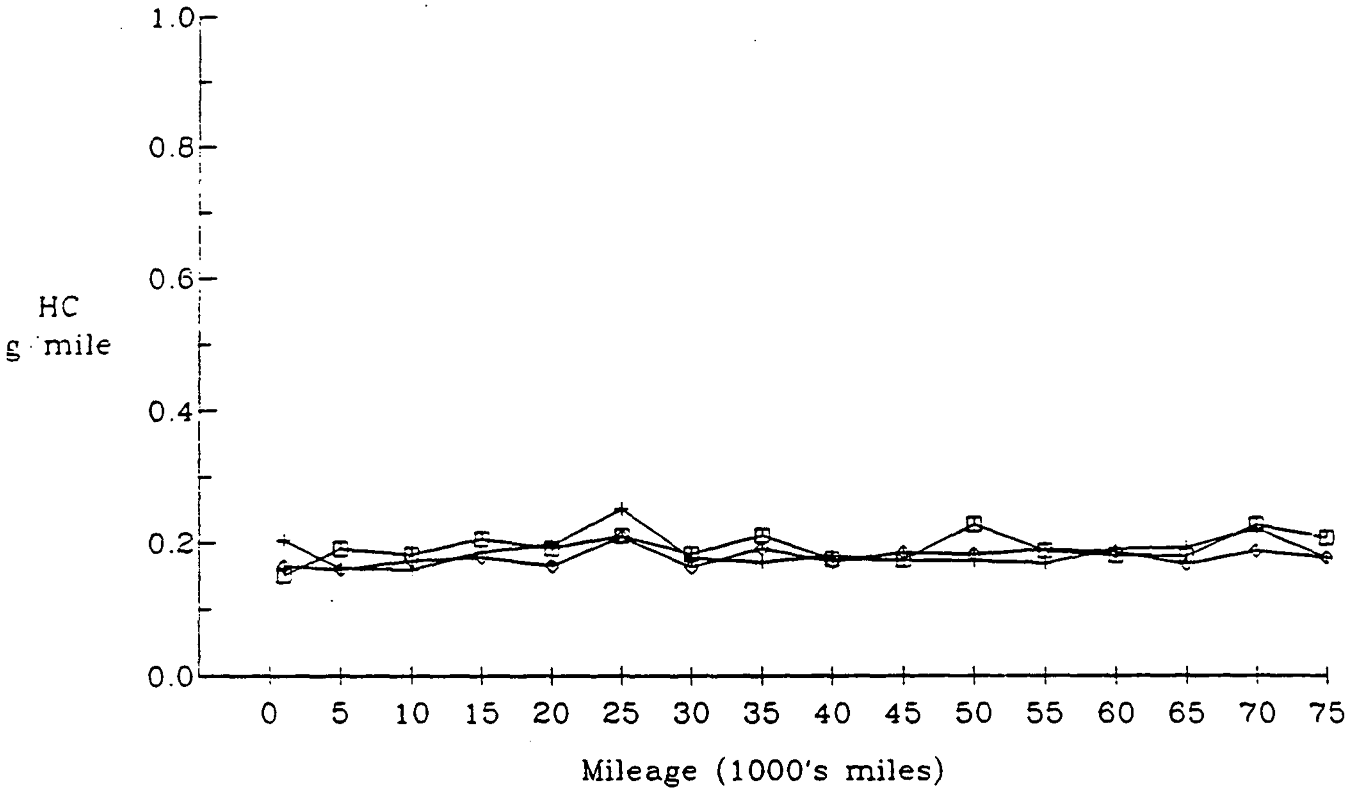
HiTEC 3000 cars



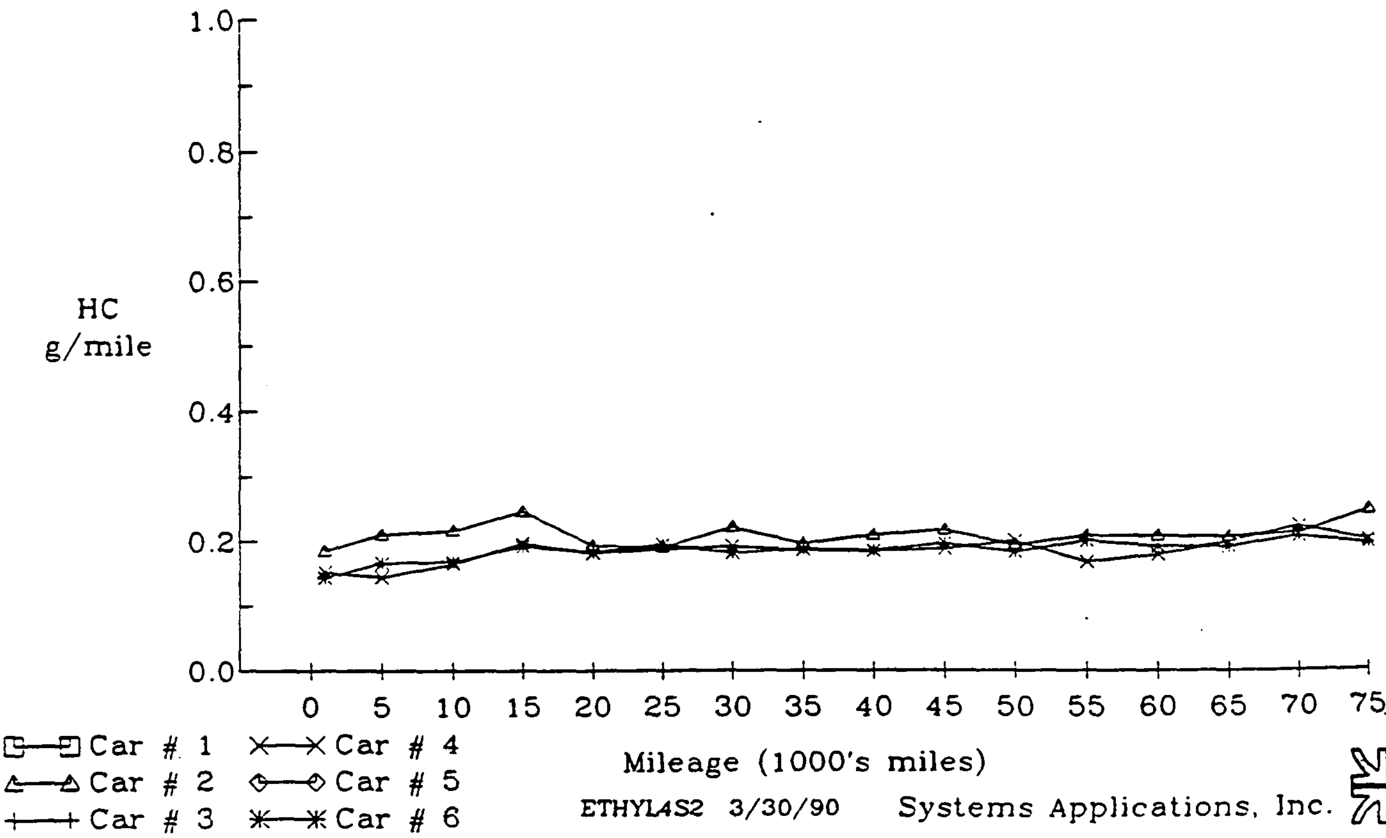
ETHYL4S2 3/30/90 Systems Applications, Inc.

Average Tailpipe Hydrocarbon Emissions for Model Group I

EEE cars

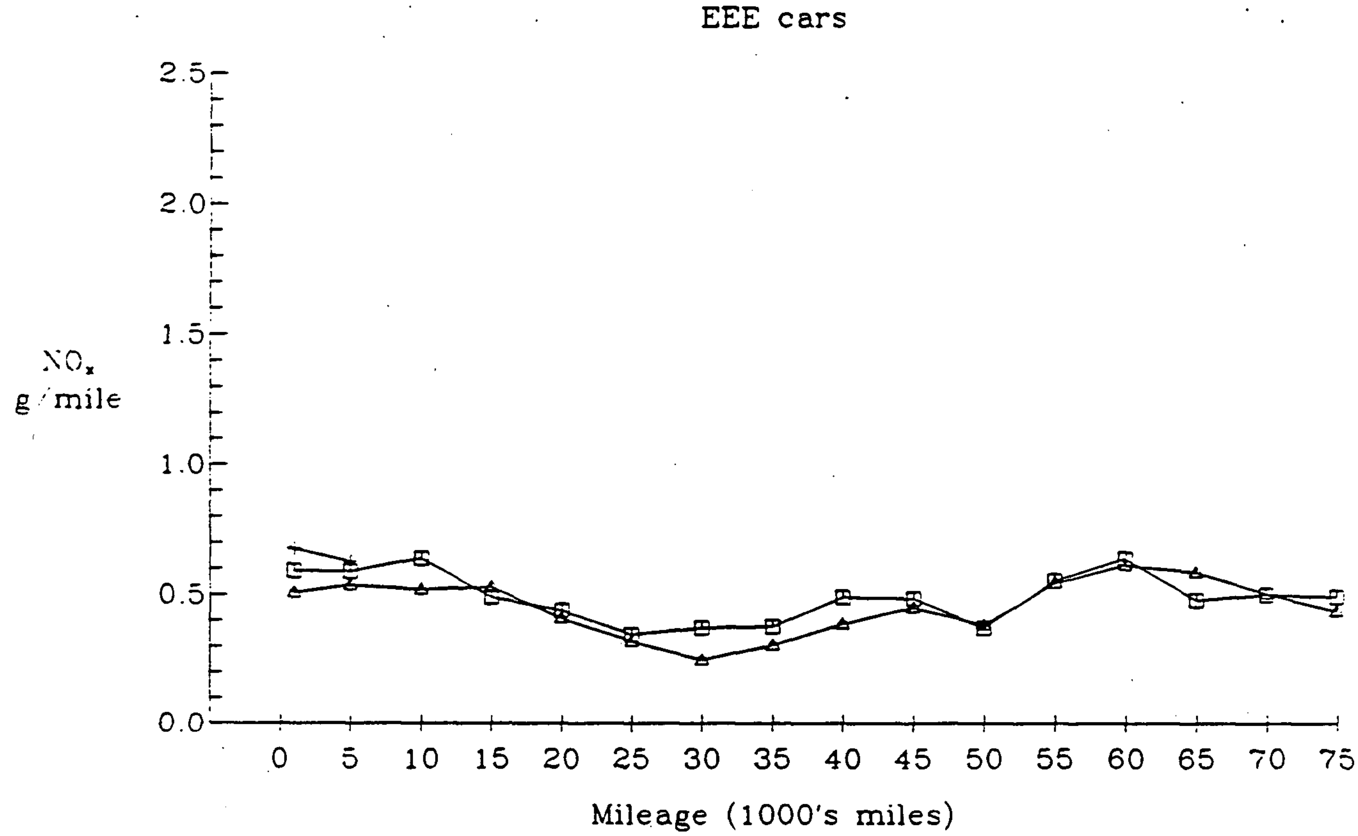


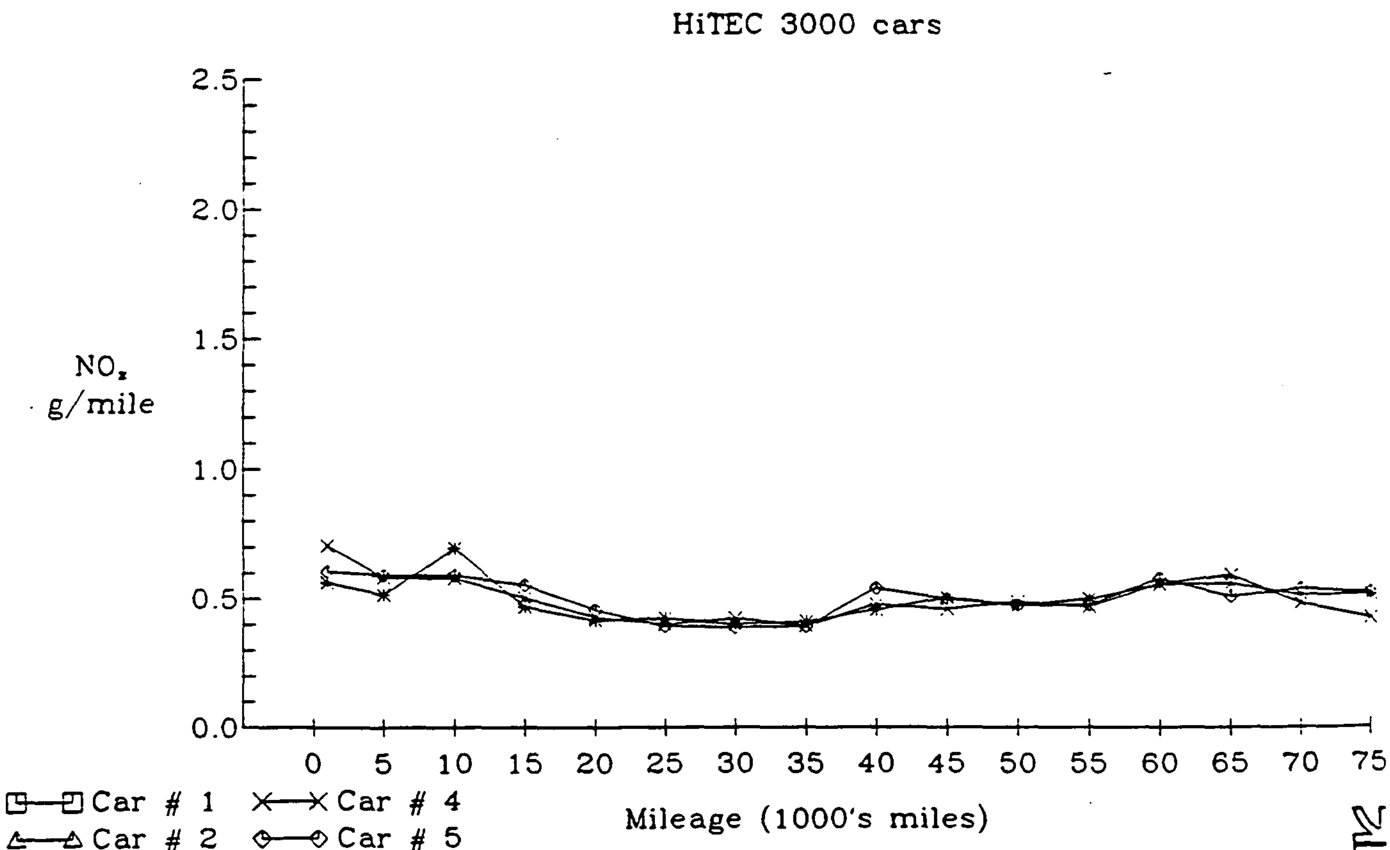
HiTEC 3000 cars



ETHYL4S2 3/30/90 Systems Applications, Inc.

Average Tailpipe Nitrogen Oxides Emissions for Model Group D

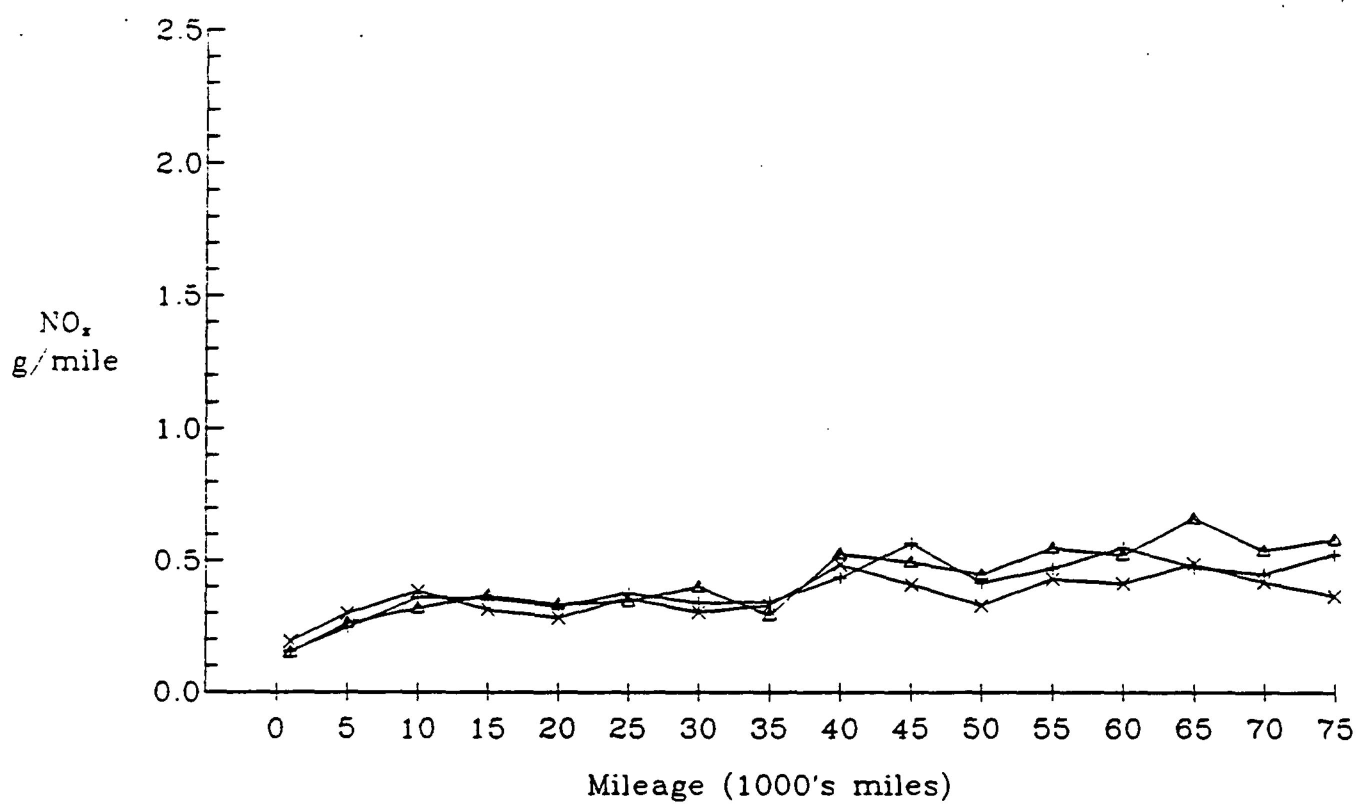




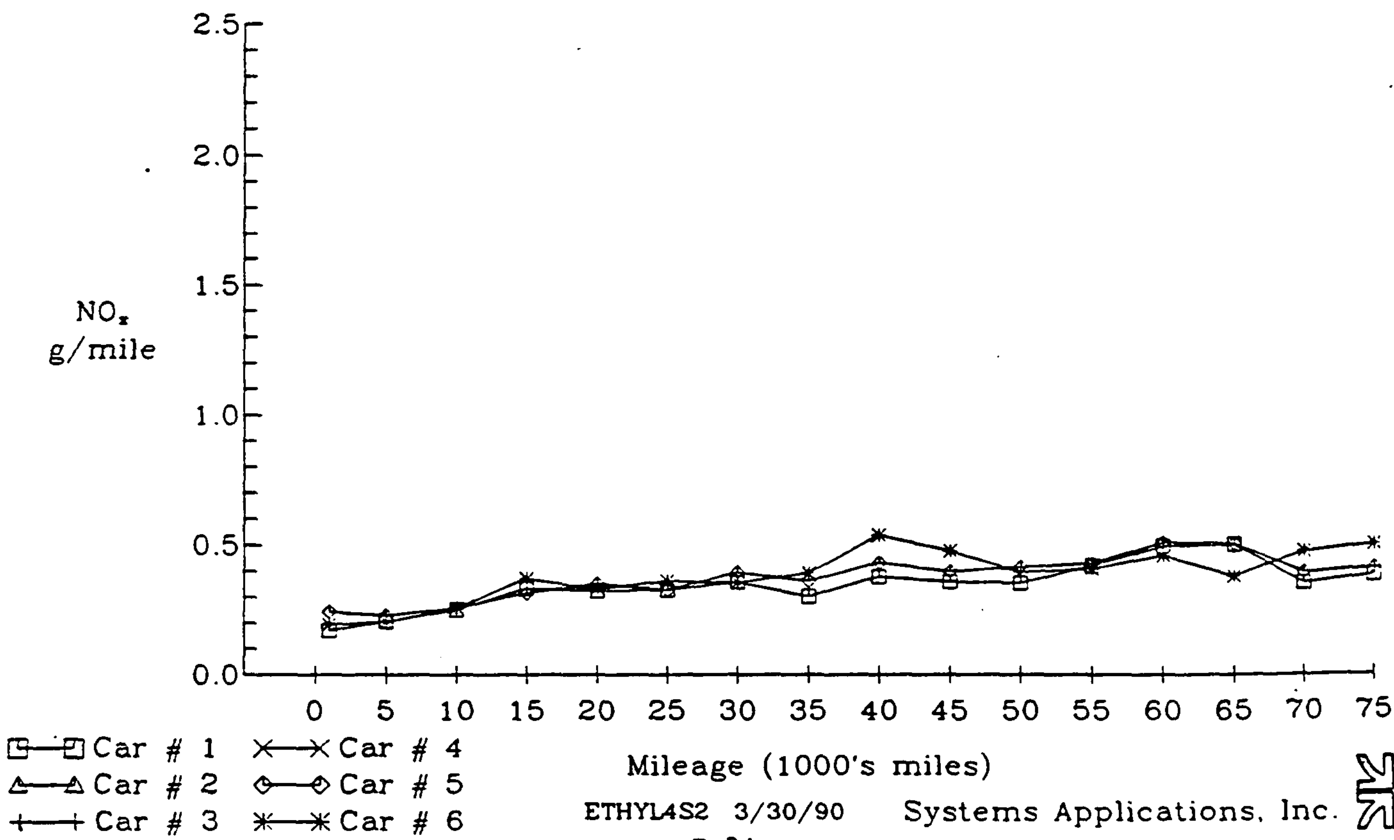
ETHYL4S2 3/30/90 Systems Applications, Inc.

Average Tailpipe Nitrogen Oxides Emissions
for Model Group E

EEE cars



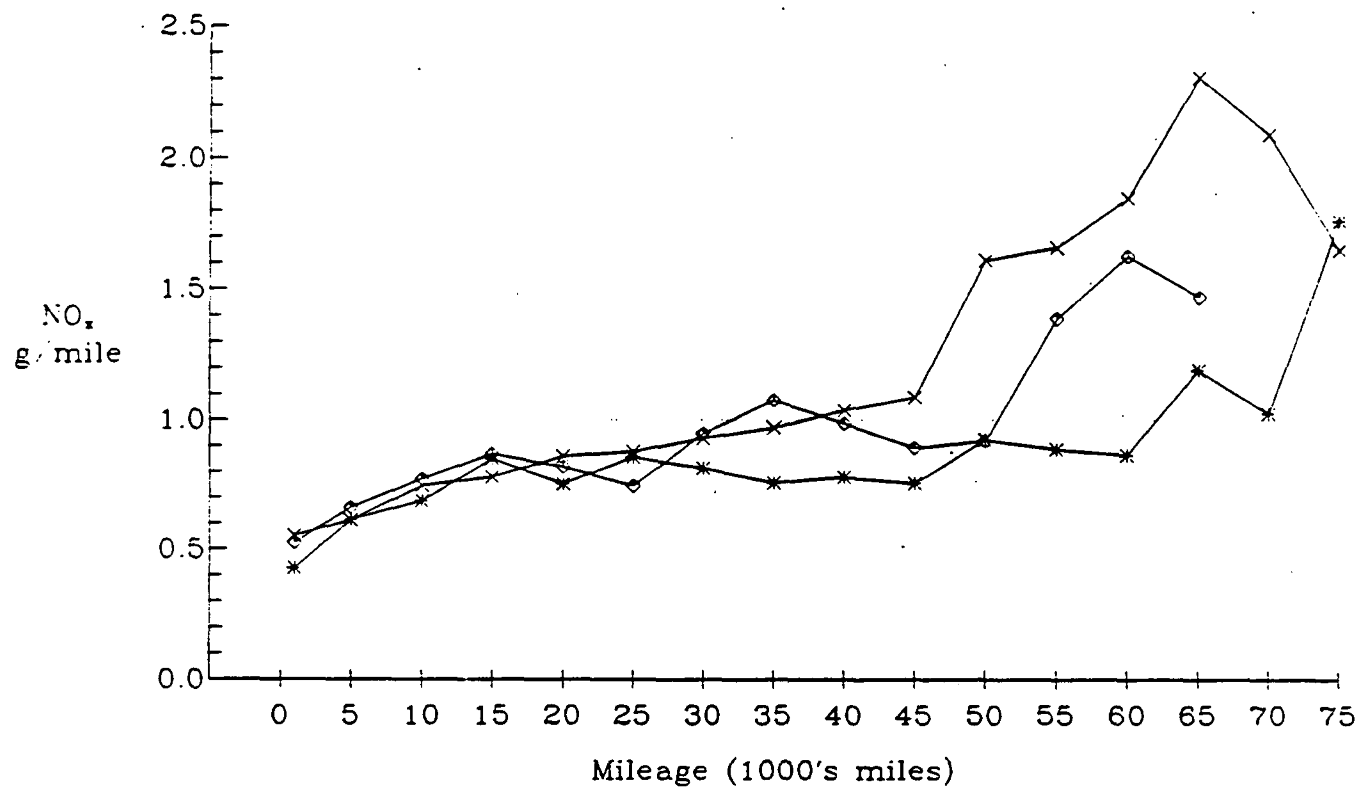
HiTEC 3000 cars



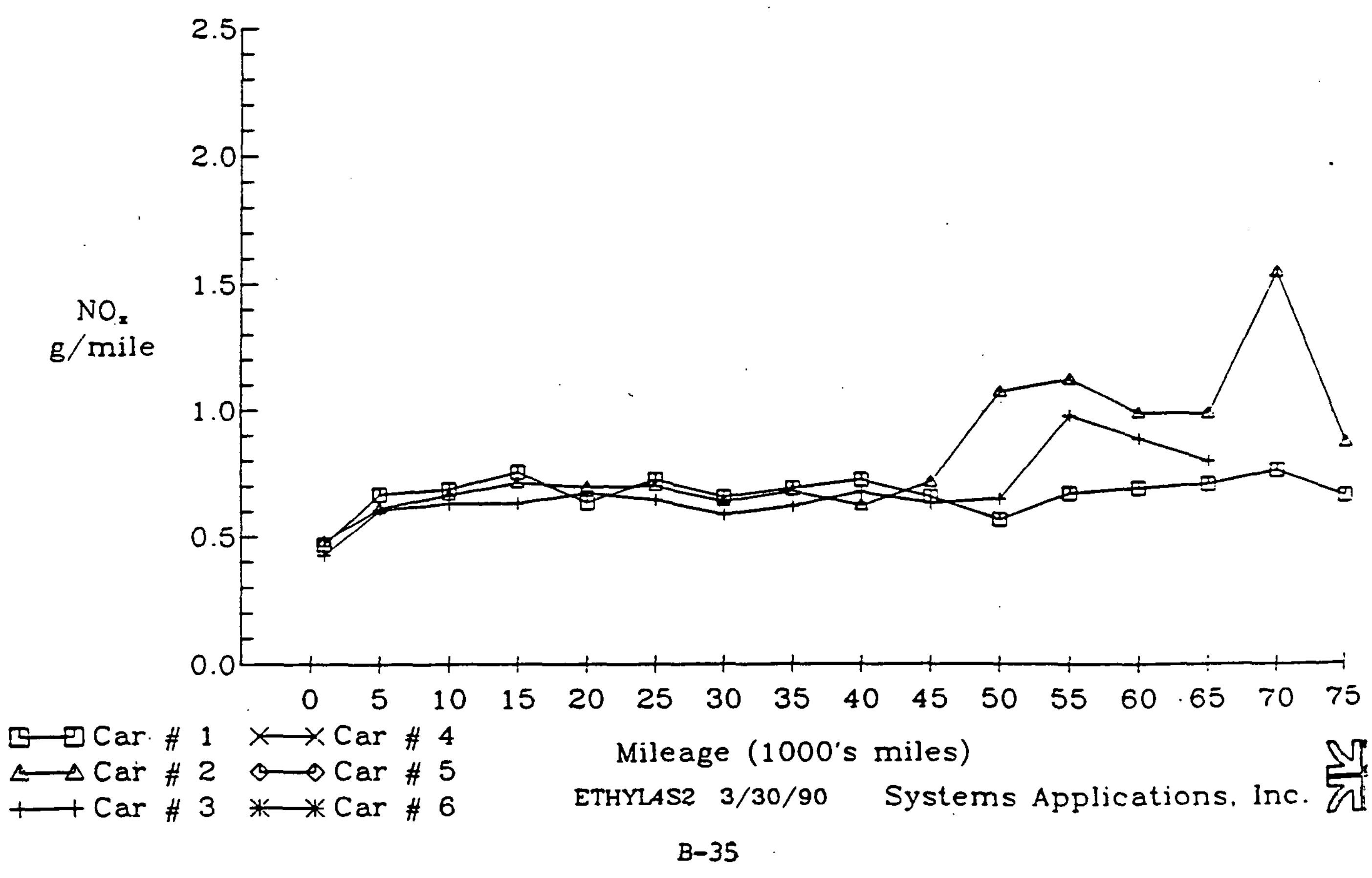
ETHYL4S2 3/30/90 Systems Applications, Inc.

Average Tailpipe Nitrogen Oxides Emissions
for Model Group F

EEE cars



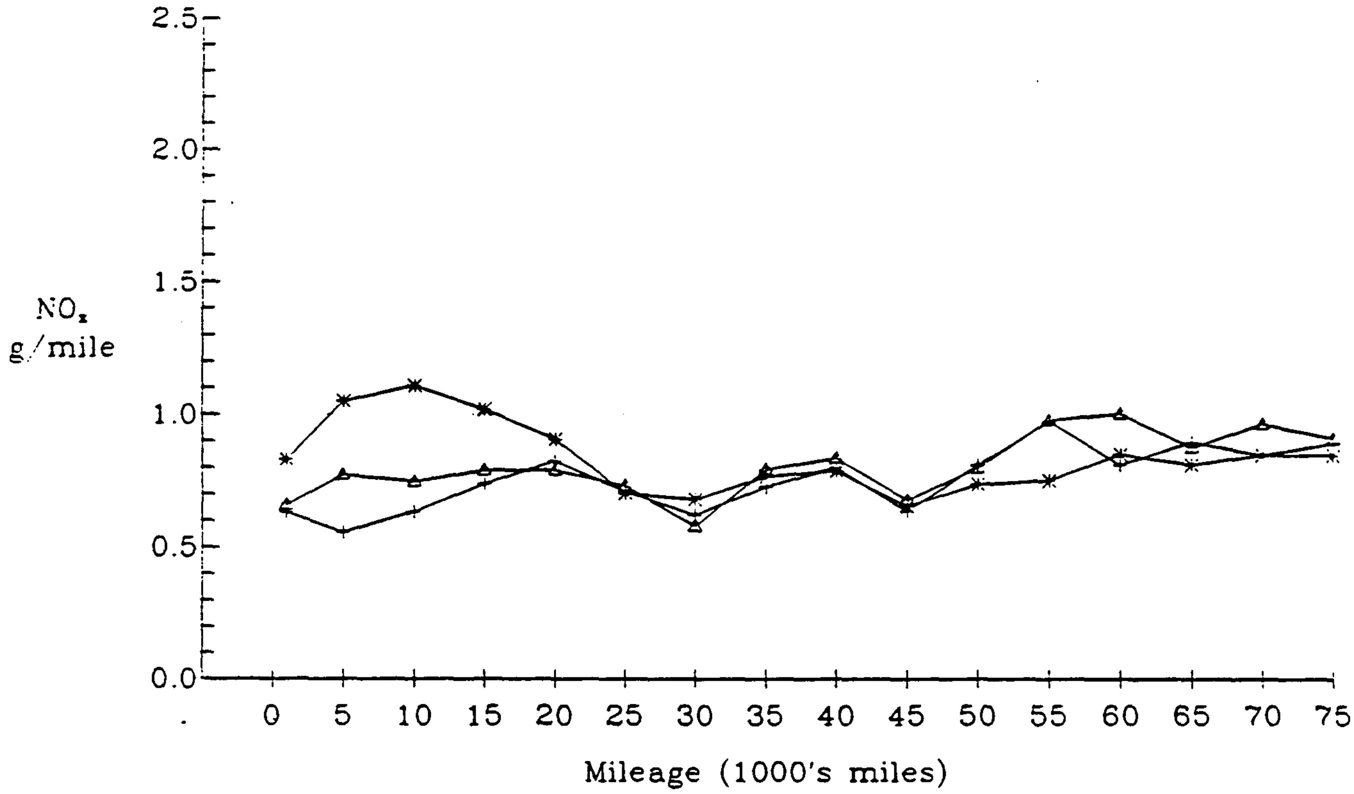
HiTEC 3000 cars



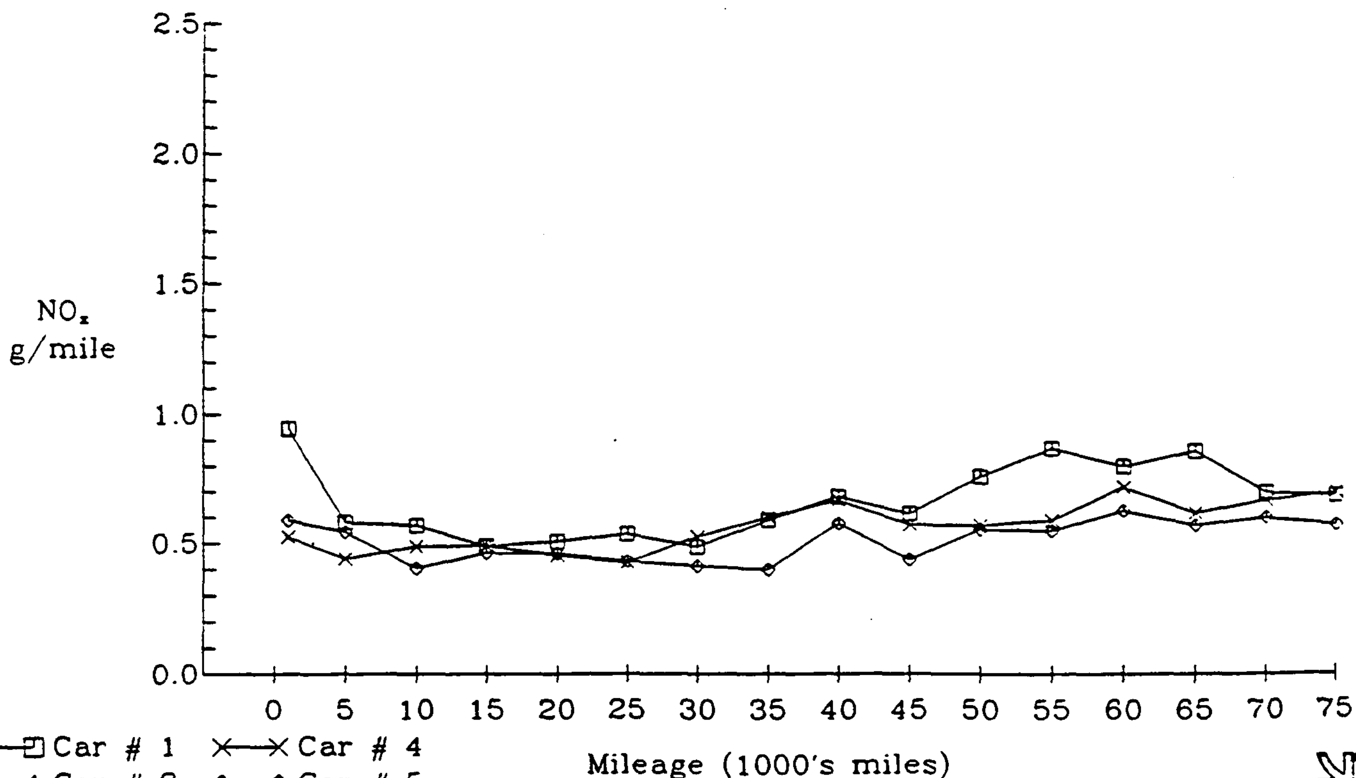
ETHYL4S2 3/30/90 Systems Applications, Inc.

Average Tailpipe Nitrogen Oxides Emissions
for Model Group T

EEE cars



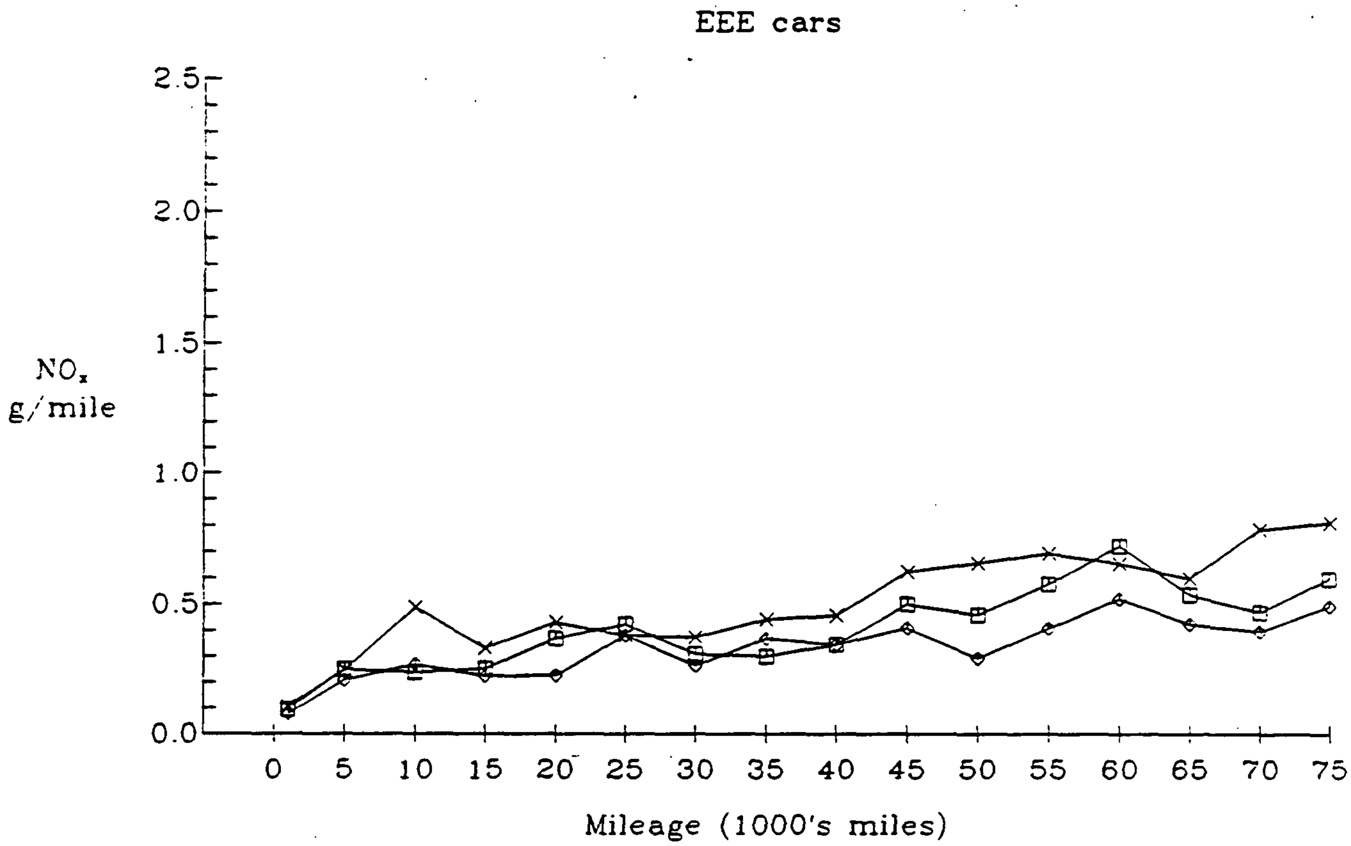
HiTEC 3000 cars

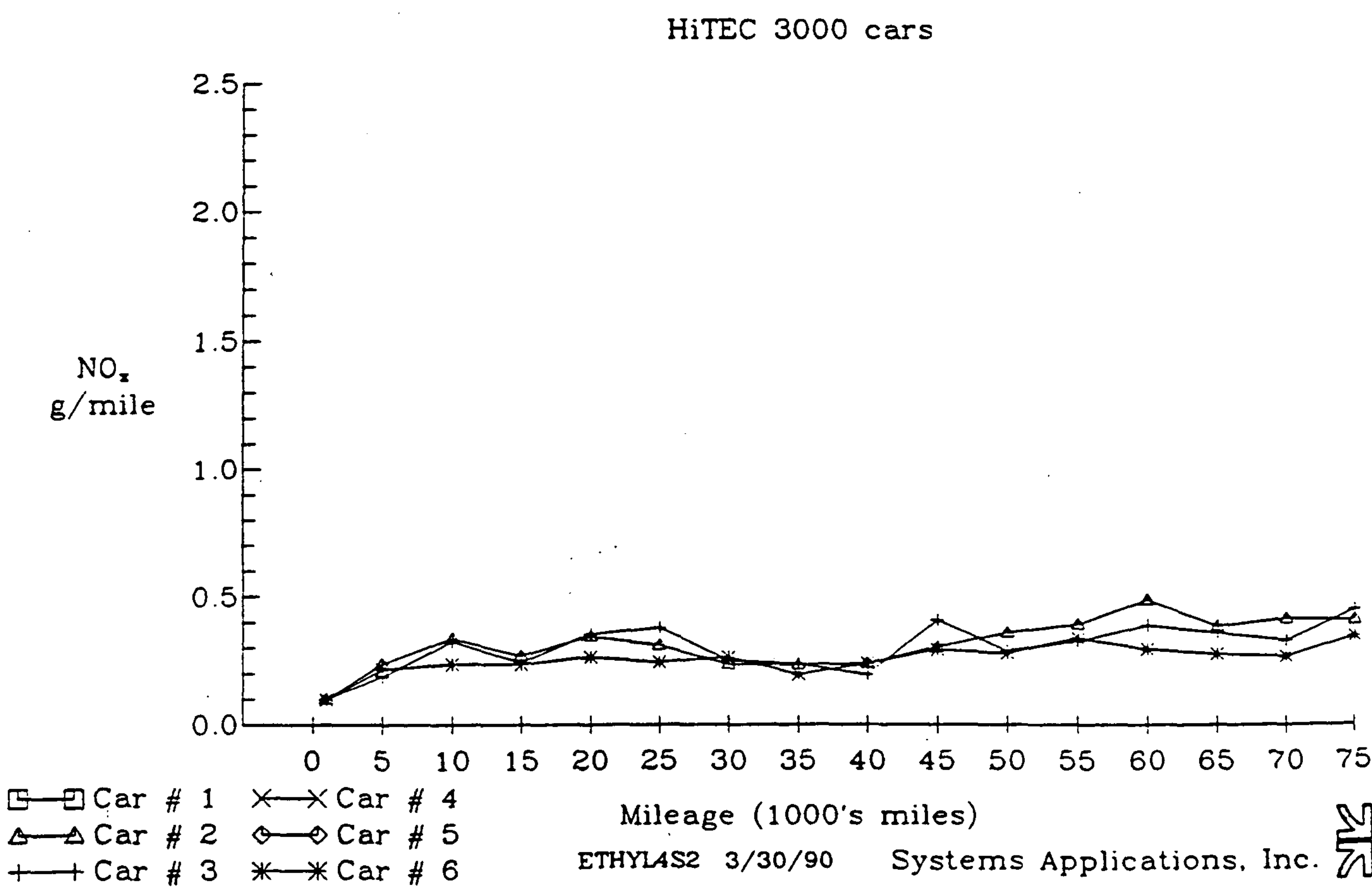


Car # 1   Car # 4
Car # 2   Car # 5
Car # 3   Car # 6

ETHYL4S2 3/30/90 Systems Applications, Inc.

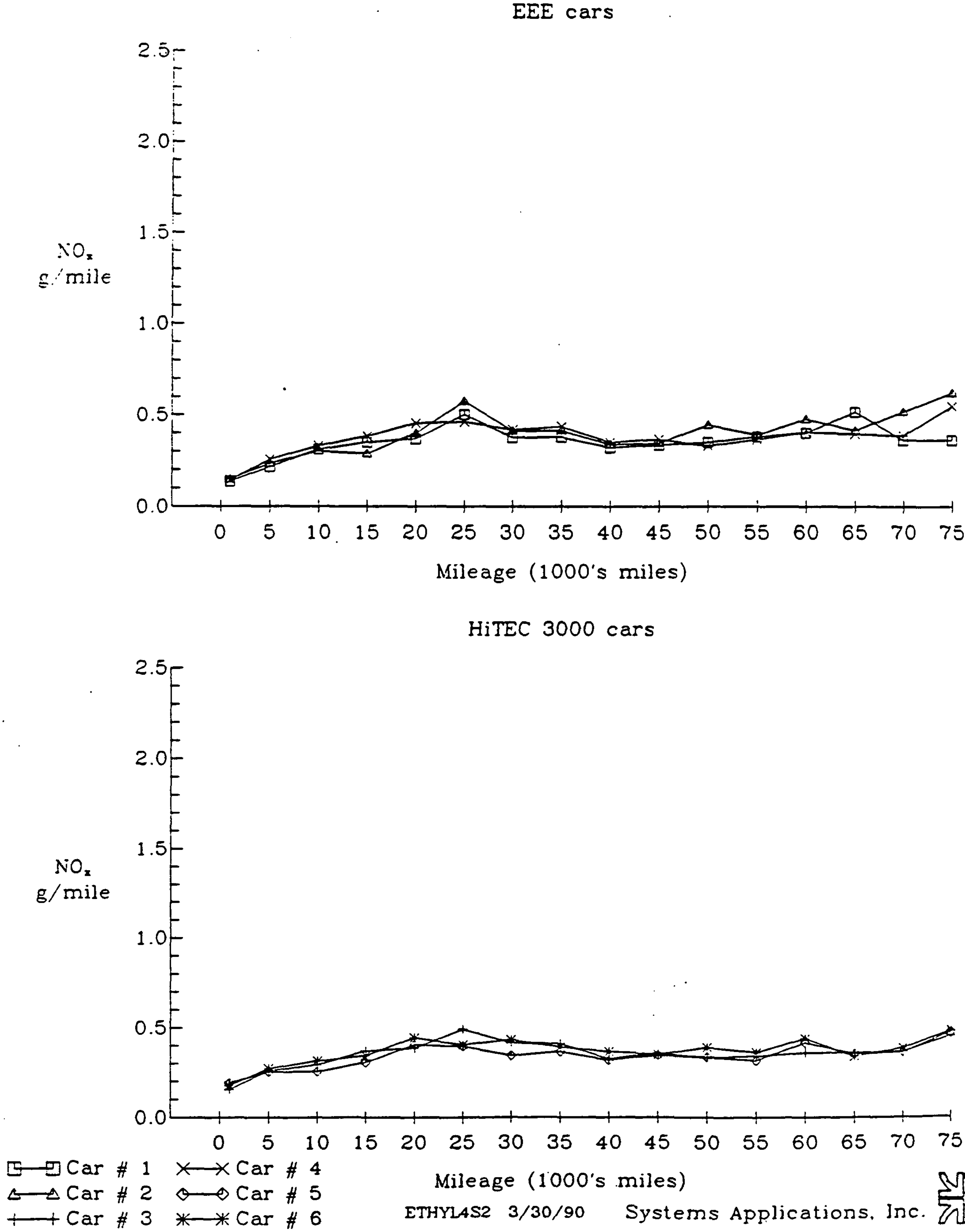
Average Tailpipe Nitrogen Oxides Emissions for Model Group C





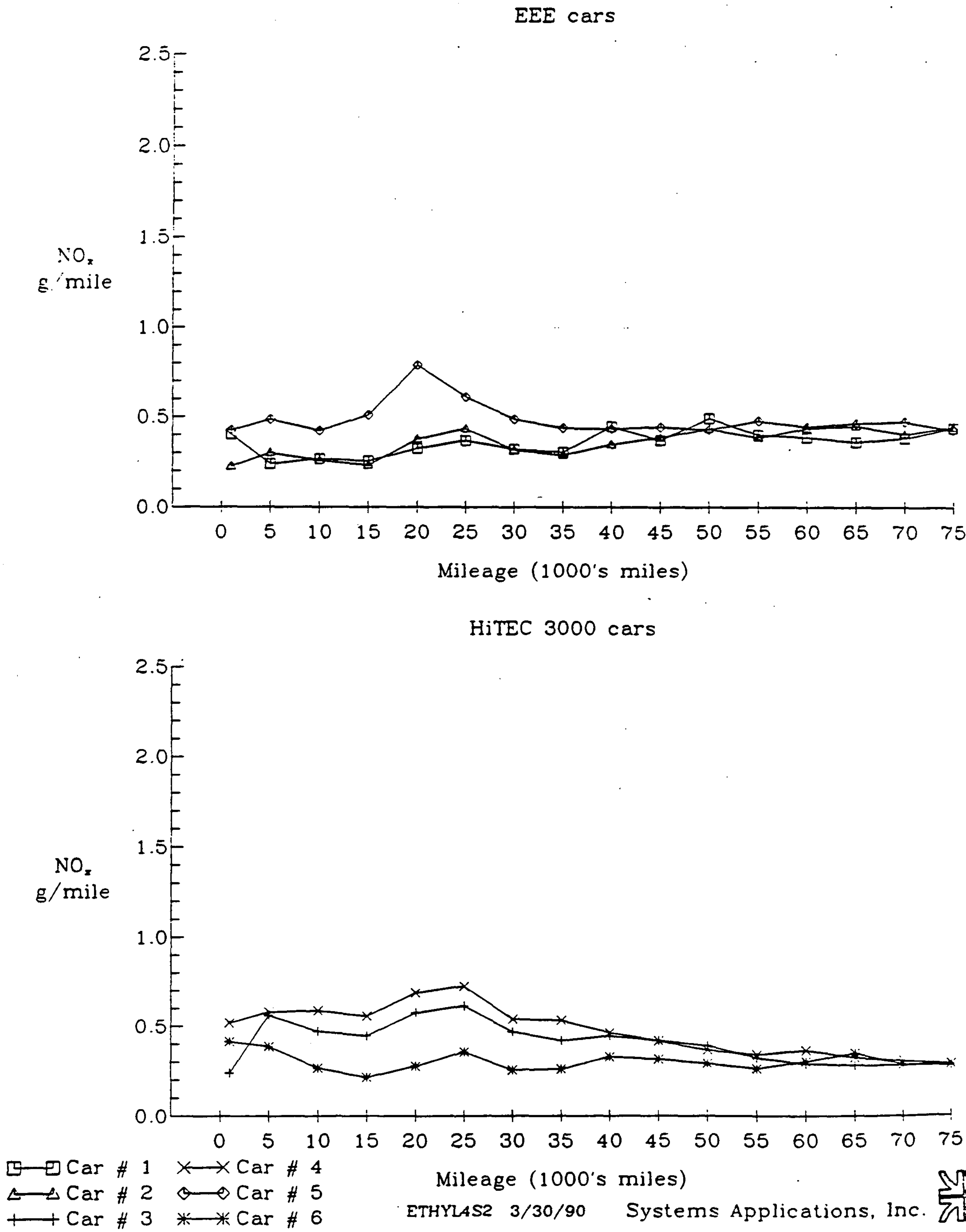
ETHYL4S2 3/30/90 Systems Applications, Inc.

Average Tailpipe Nitrogen Oxides Emissions for Model Group G



ETHYL4S2 3/30/90 Systems Applications, Inc.

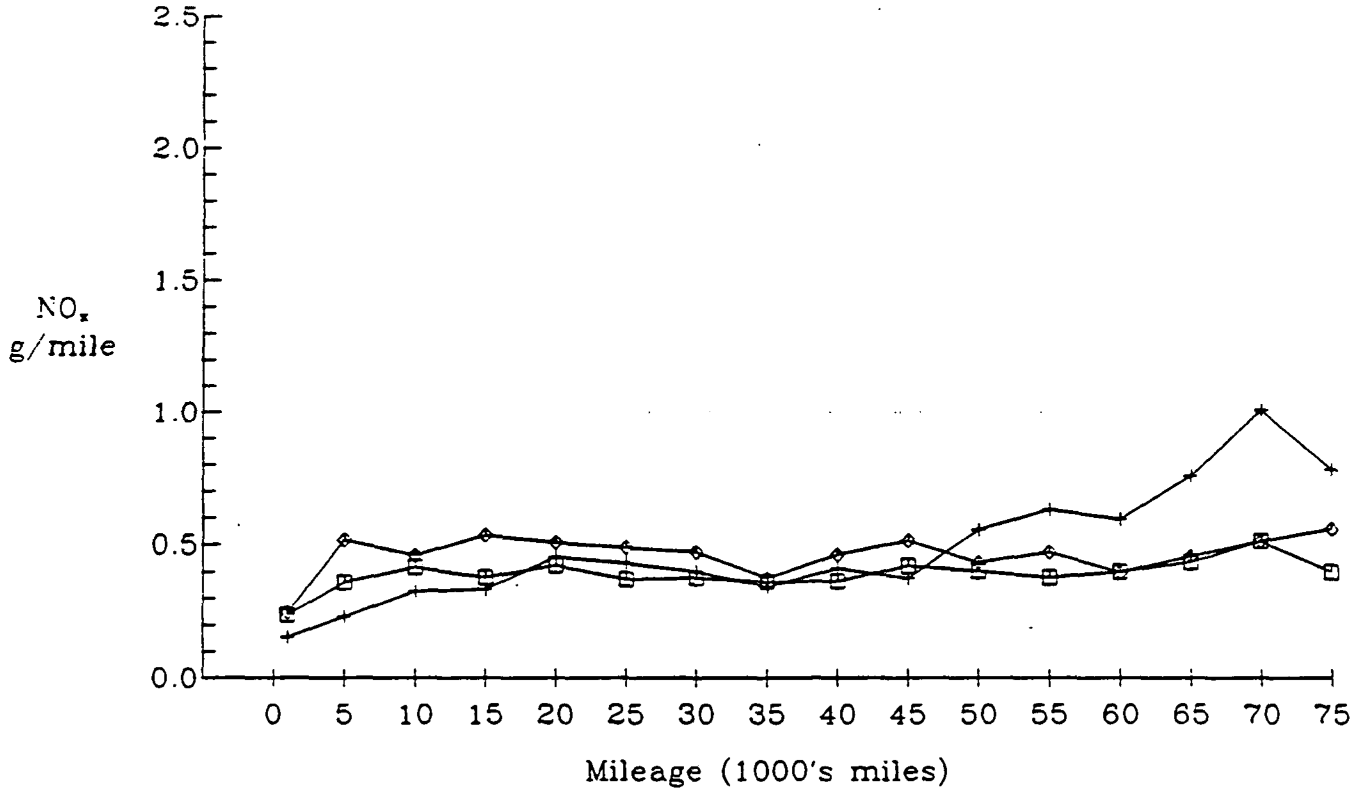
Average Tailpipe Nitrogen Oxides Emissions for Model Group H



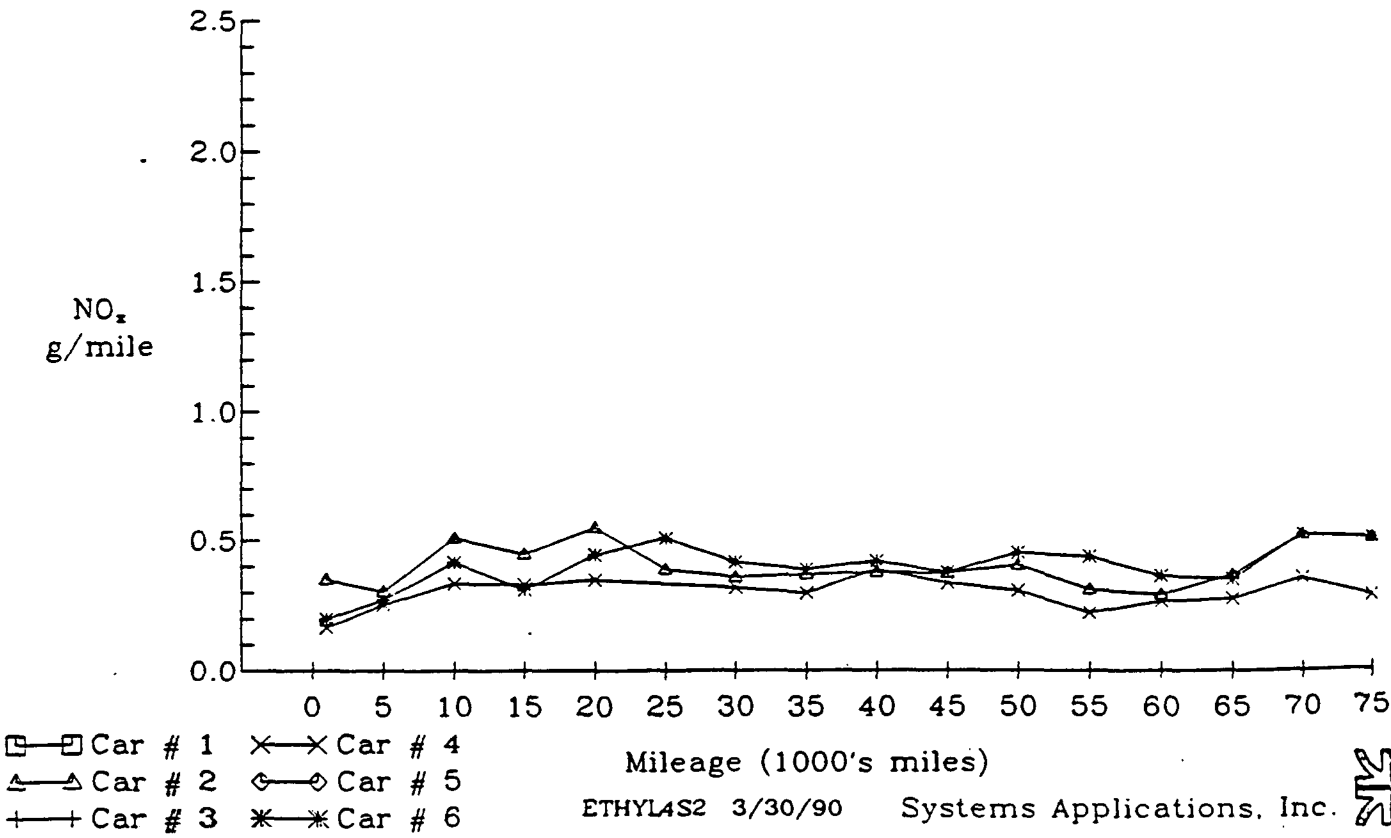
ETHYL4S2 3/30/90 Systems Applications, Inc.

Average Tailpipe Nitrogen Oxides Emissions for Model Group I

EEE cars

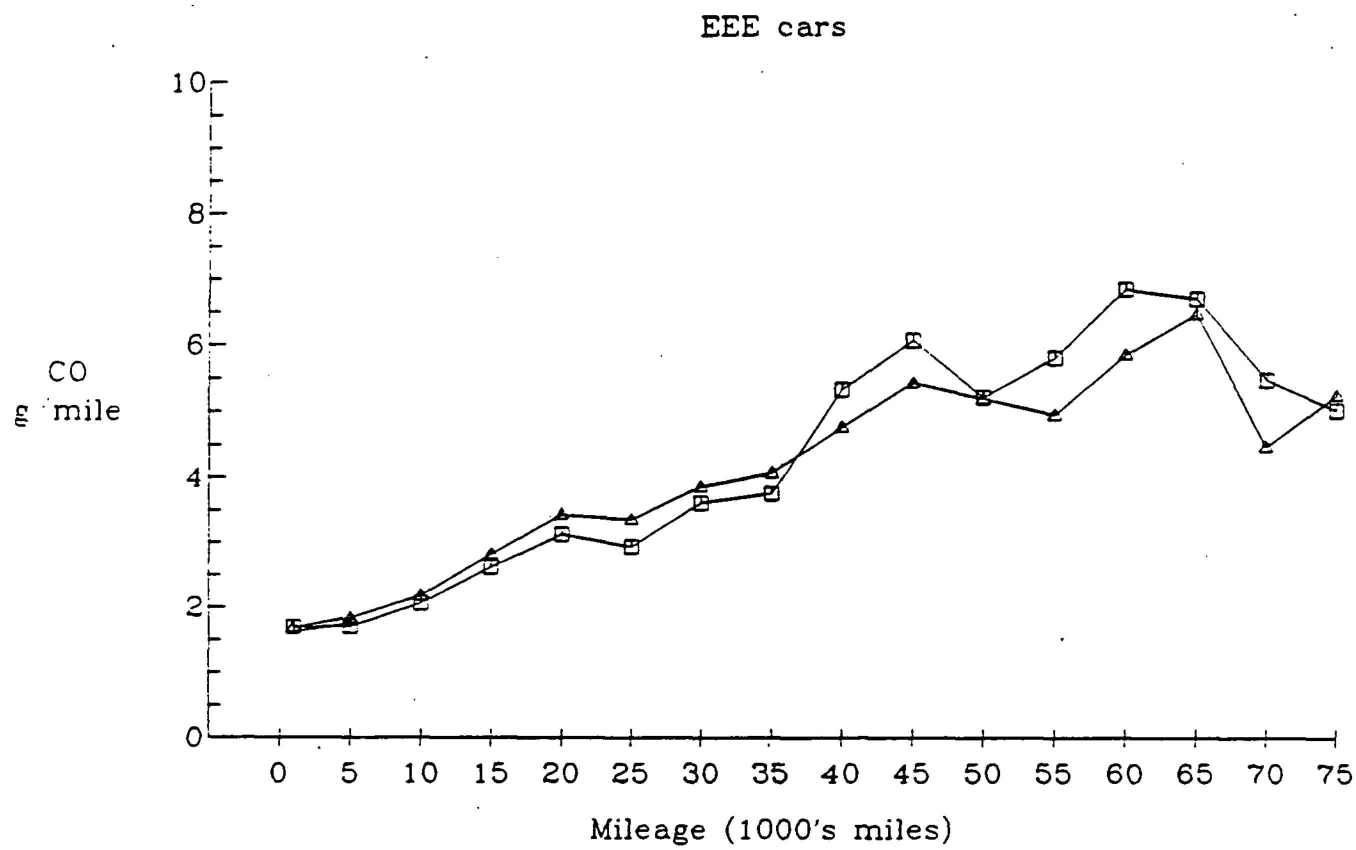


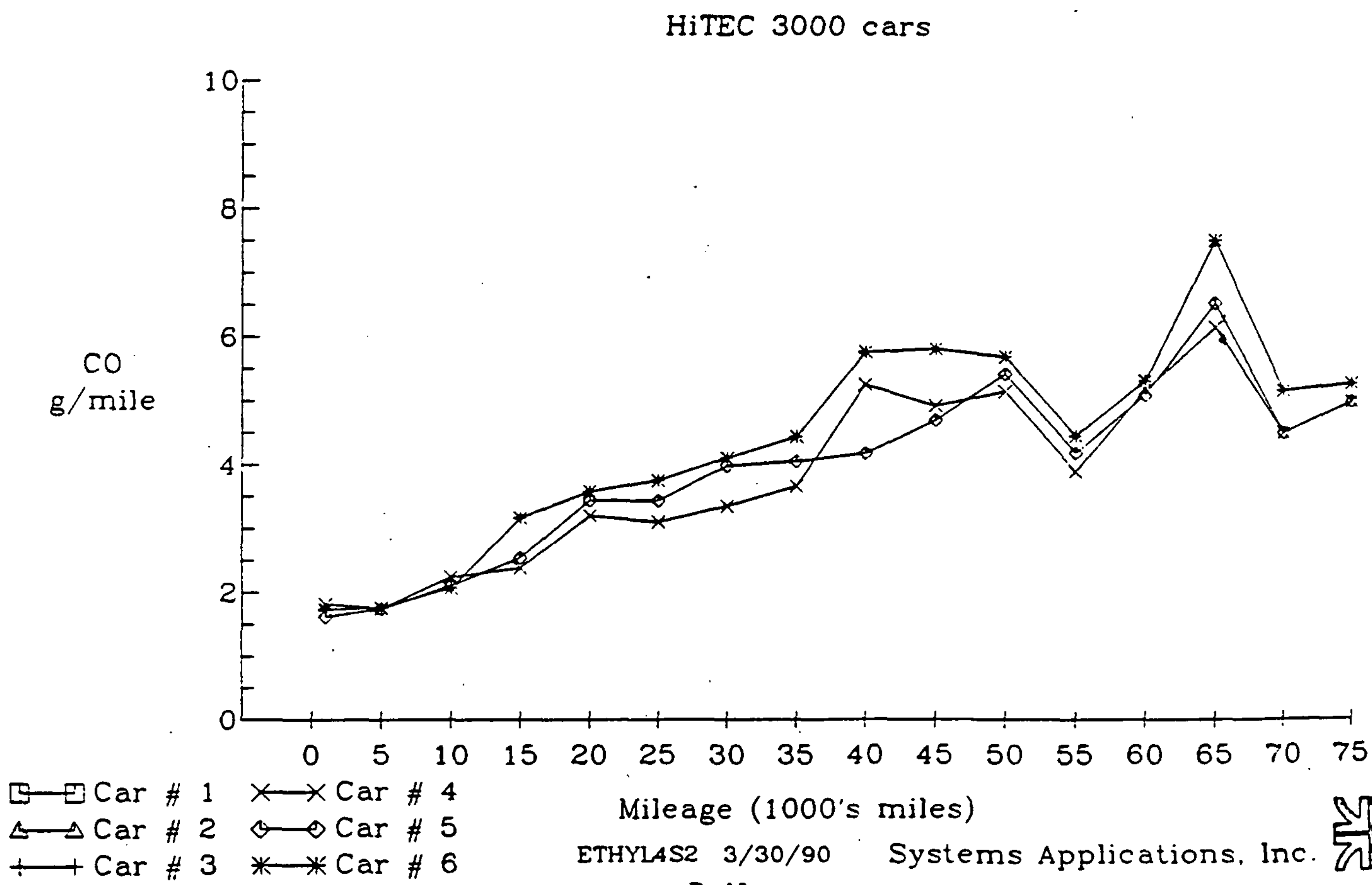
HiTEC 3000 cars



ETHYL4S2 3/30/90 Systems Applications, Inc.

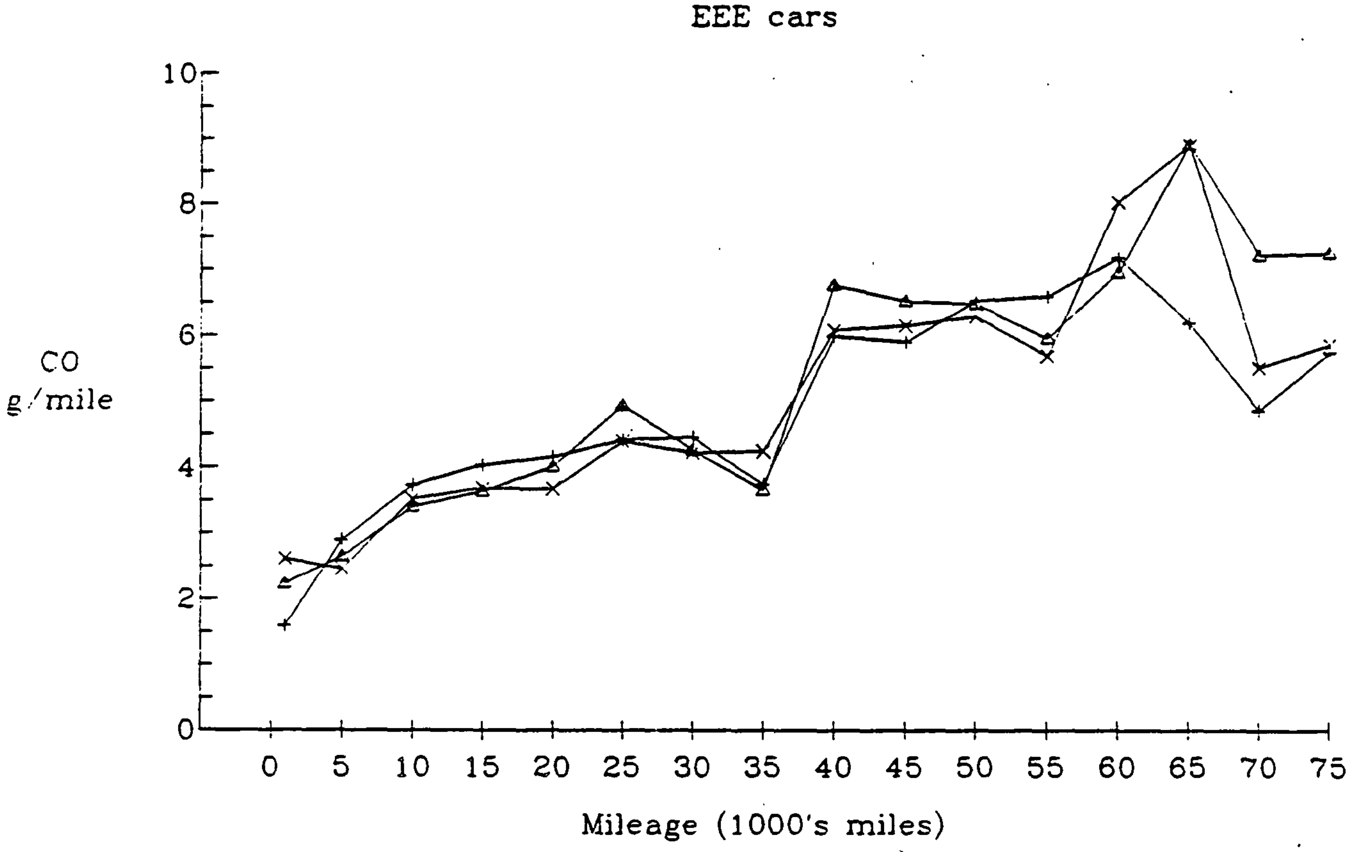
Average Tailpipe Carbon Monoxide Emissions
for Model Group D

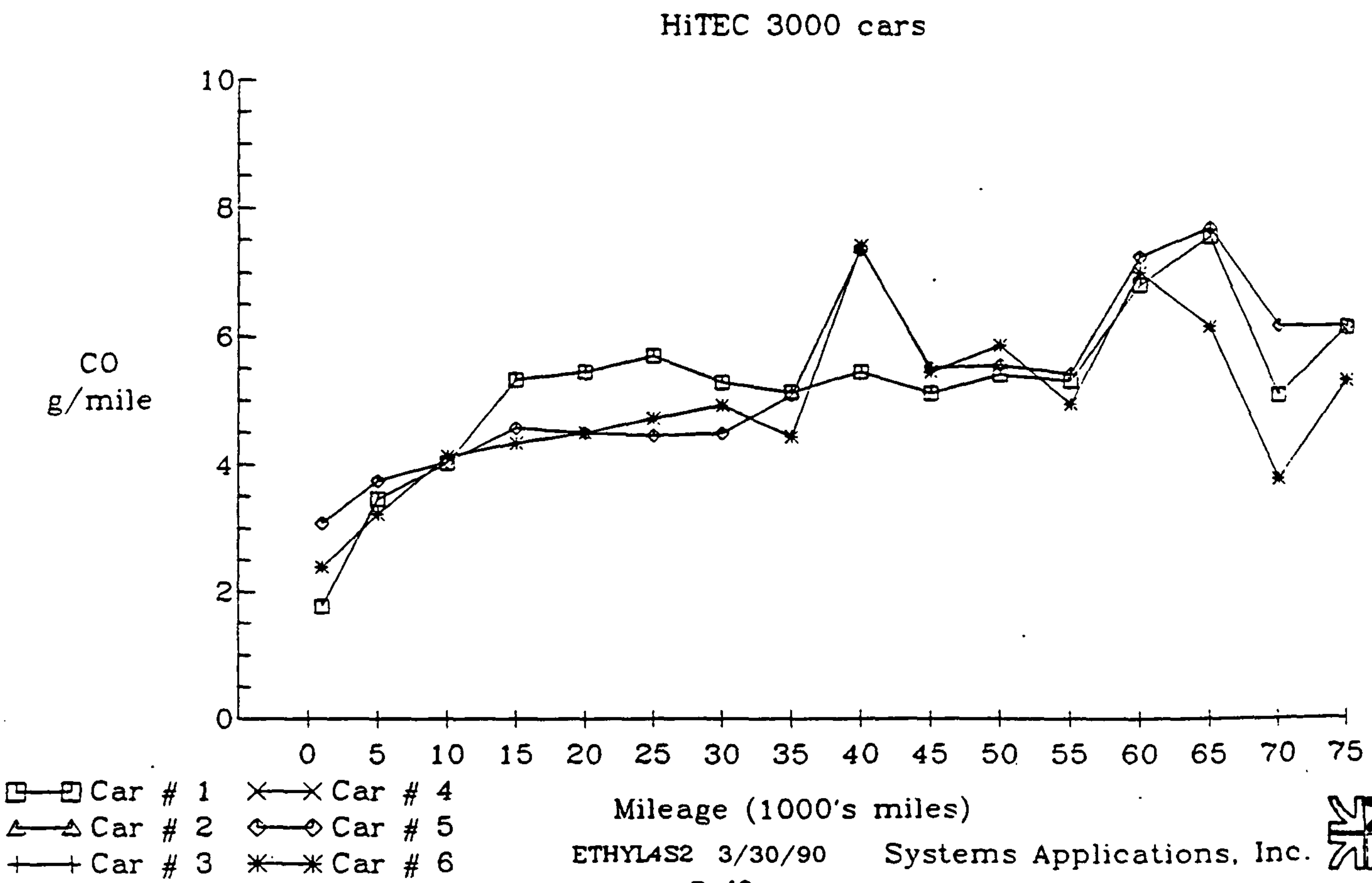




ETHYL4S2 3/30/90 Systems Applications, Inc.

Average Tailpipe Carbon Monoxide Emissions for Model Group E

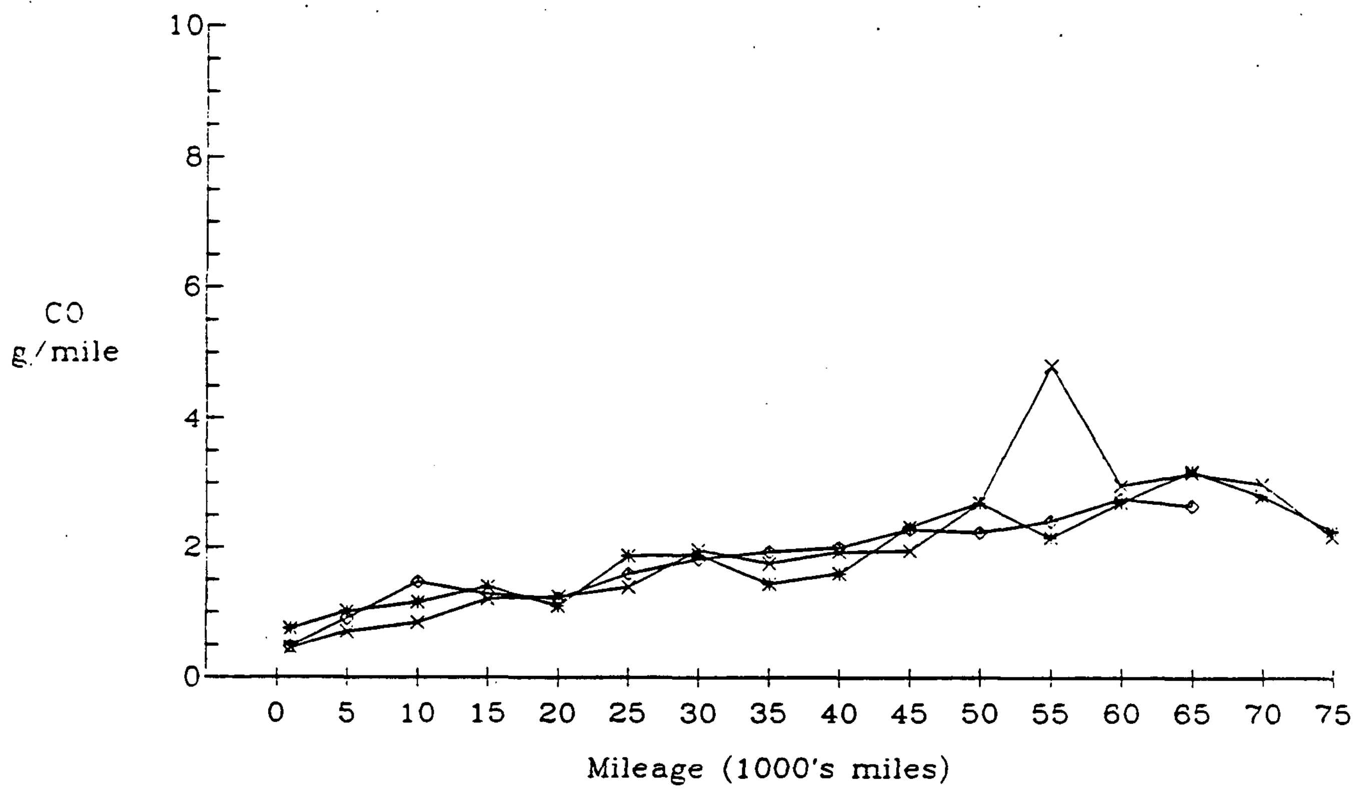




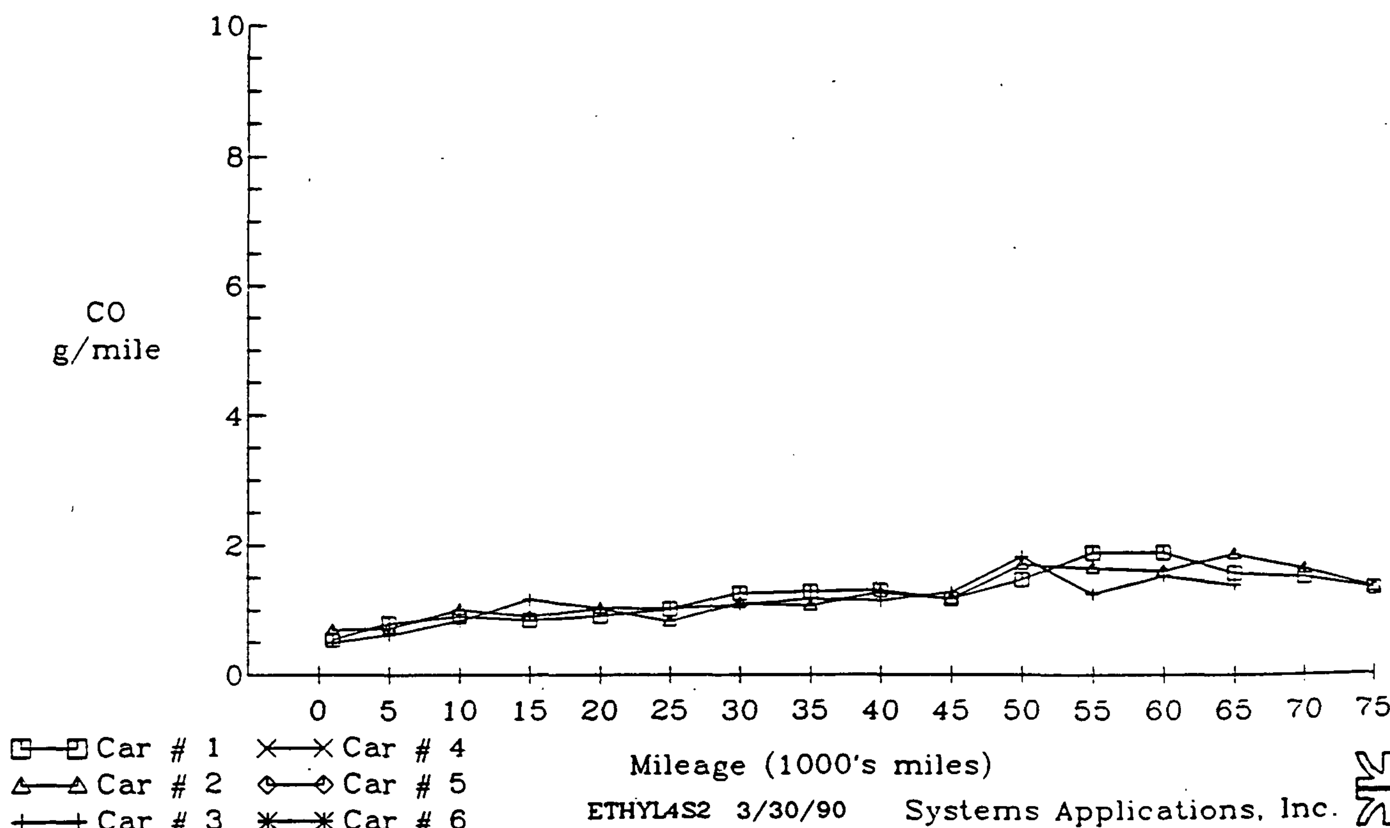
ETHYL4S2 3/30/90 Systems Applications, Inc.

Average Tailpipe Carbon Monoxide Emissions for Model Group F

EEE cars



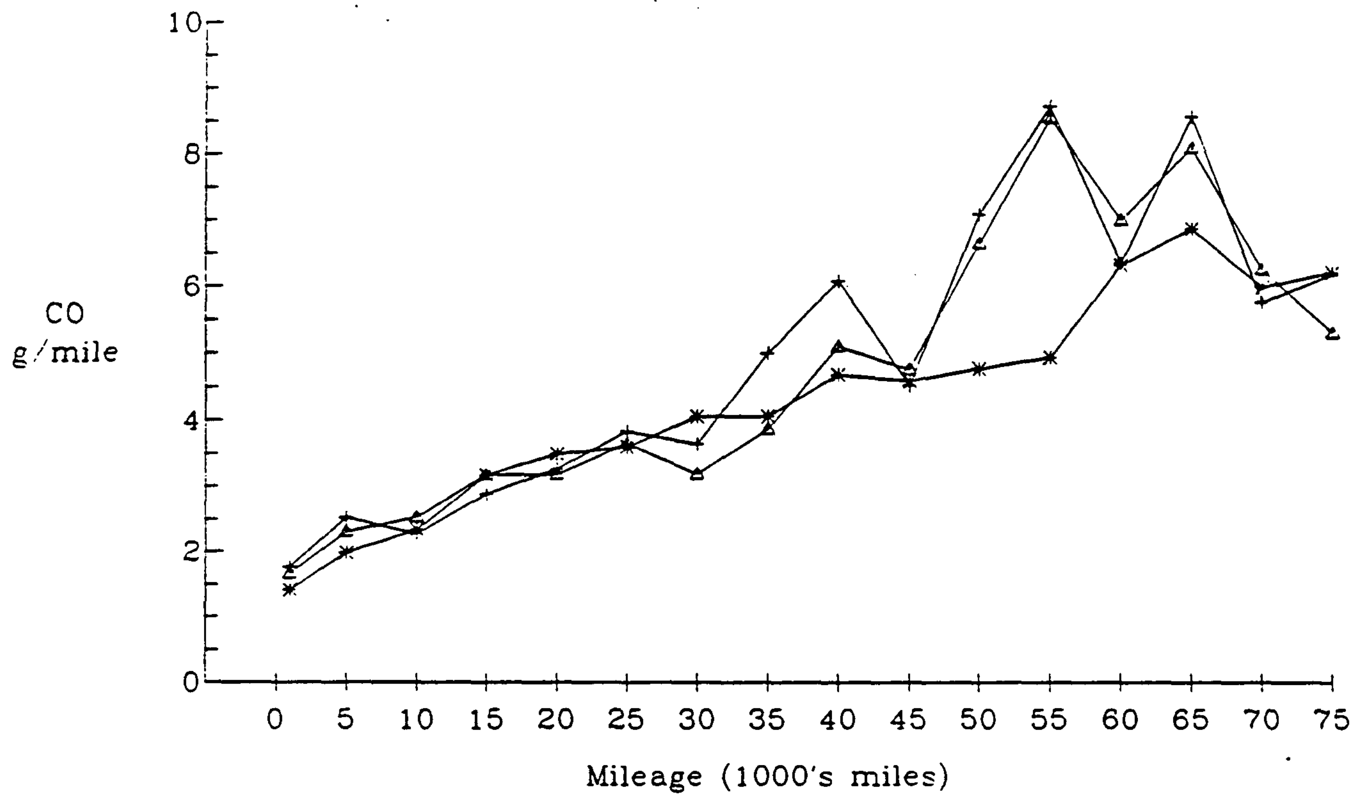
HiTEC 3000 cars



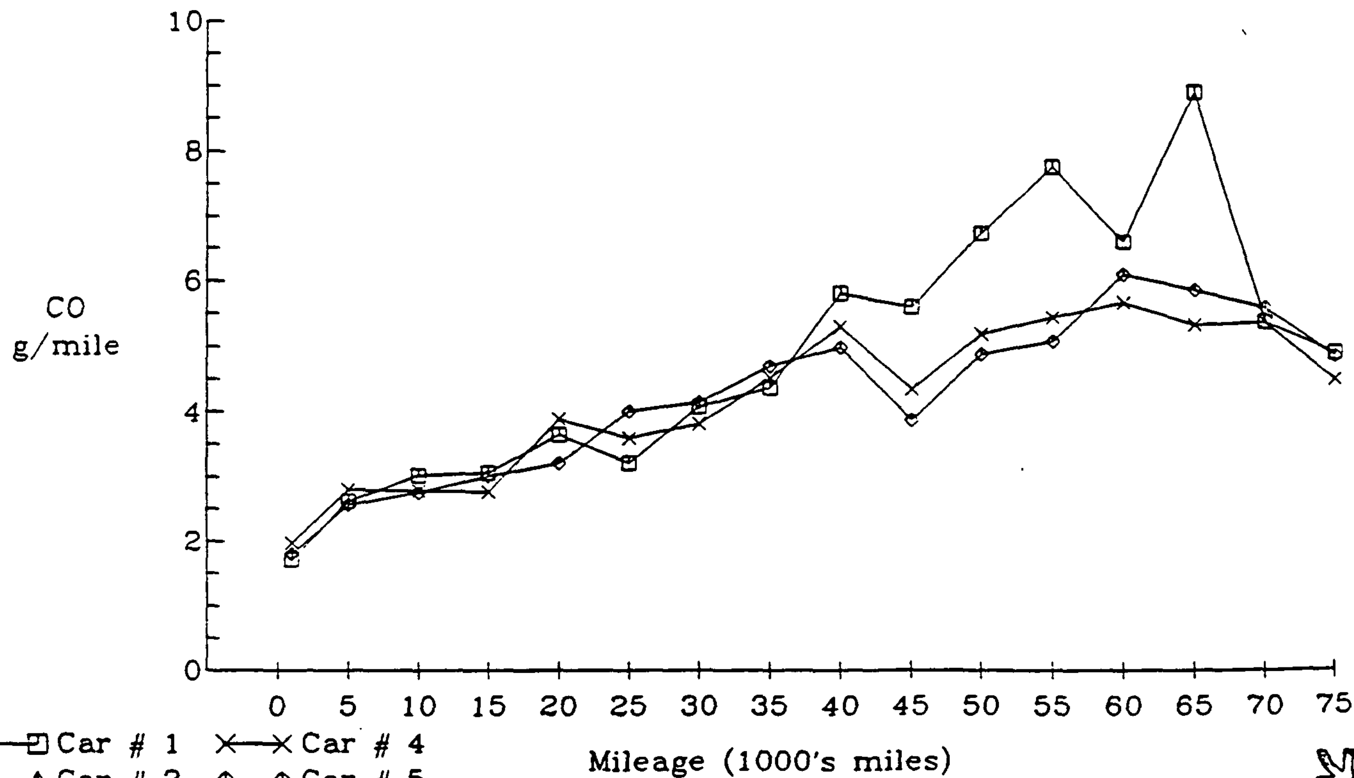
ETHYL4S2 3/30/90 Systems Applications, Inc.

Average Tailpipe Carbon Monoxide Emissions
for Model Group T

EEE cars



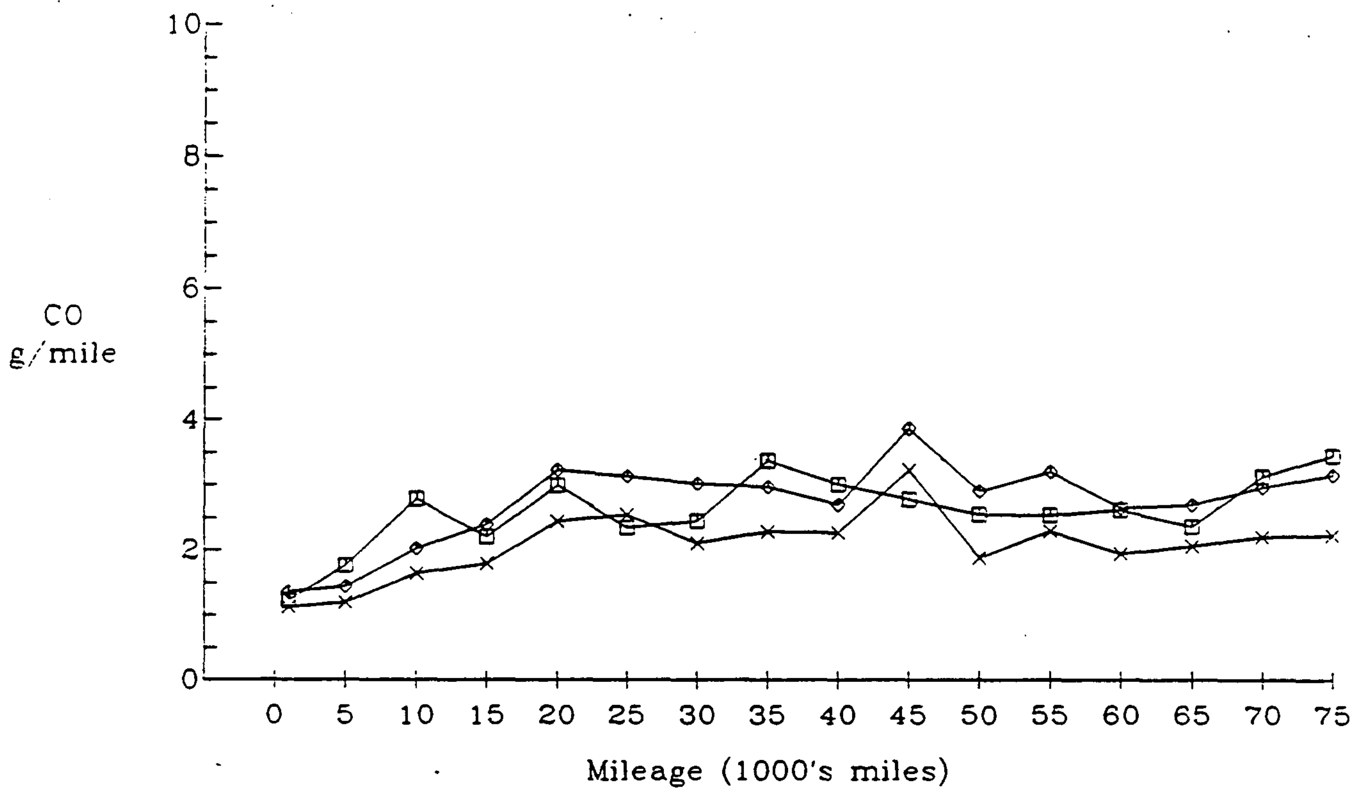
HiTEC 3000 cars



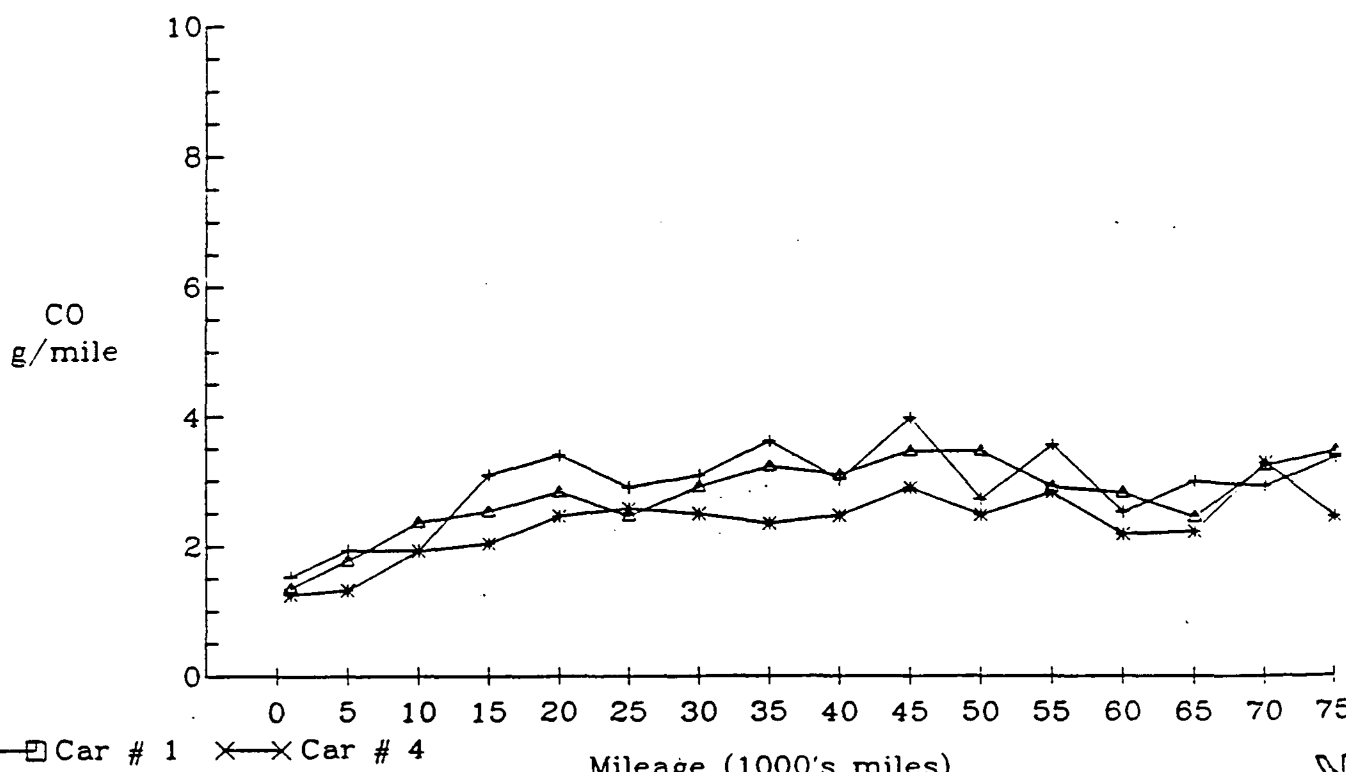
Car # 1 Car # 4
Car # 2 Car # 5
Car # 3 Car # 6

Average Tailpipe Carbon Monoxide Emissions for Model Group C

EEE cars



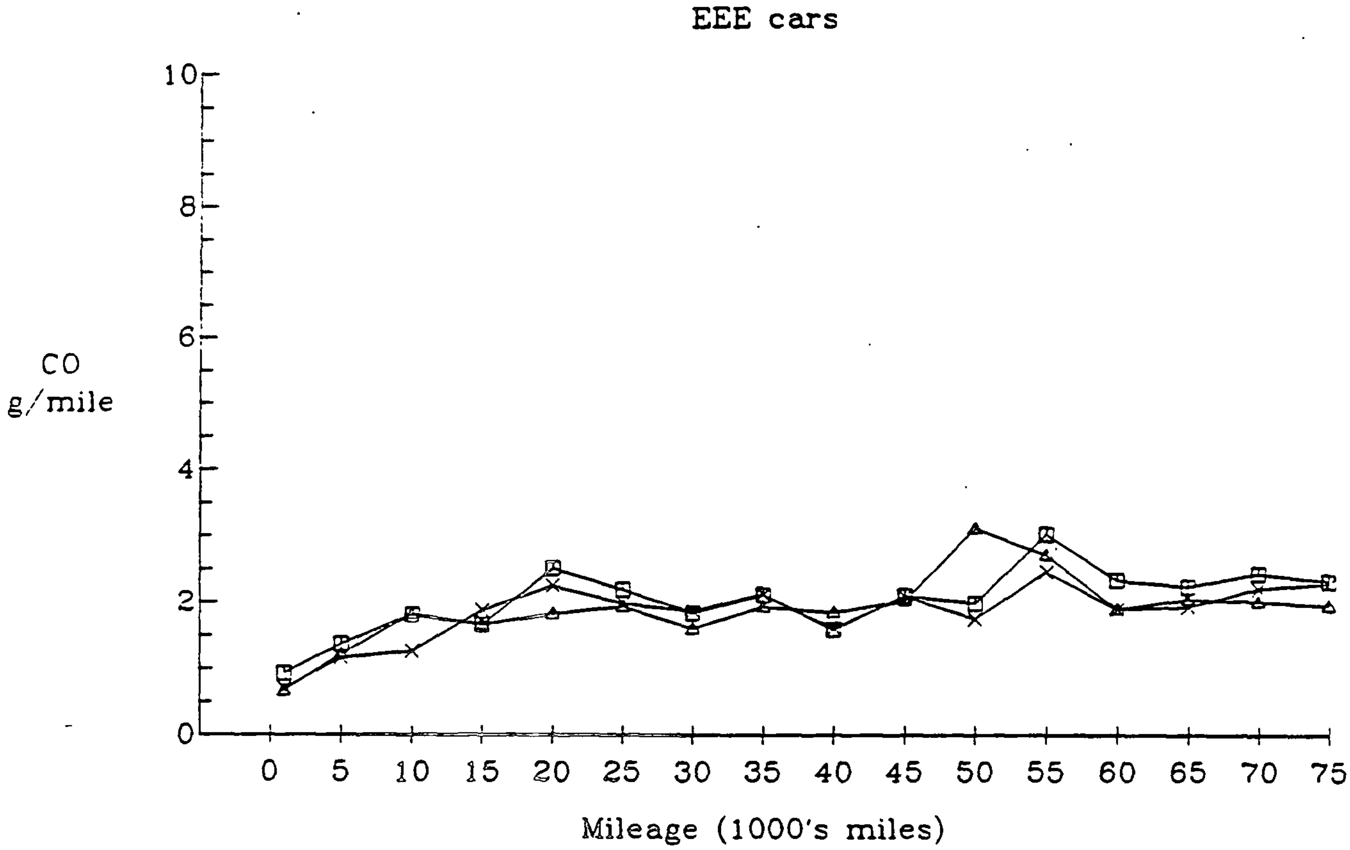
HiTEC 3000 cars

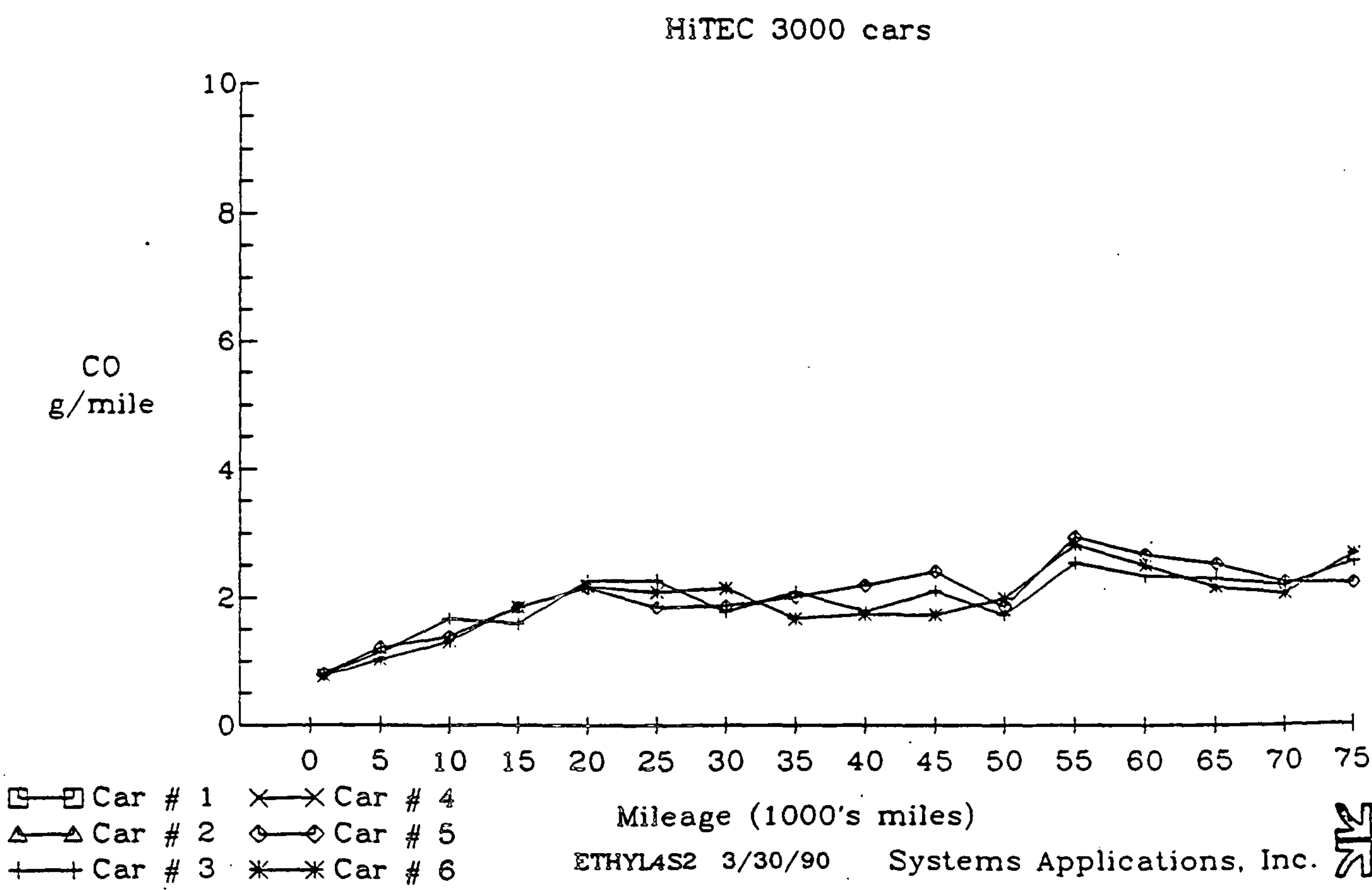


Car # 1
Car # 2
Car # 3
Car # 4
Car # 5
Car # 6

ETHYL4S2 3/30/90 Systems Applications, Inc.

Average Tailpipe Carbon Monoxide Emissions for Model Group G





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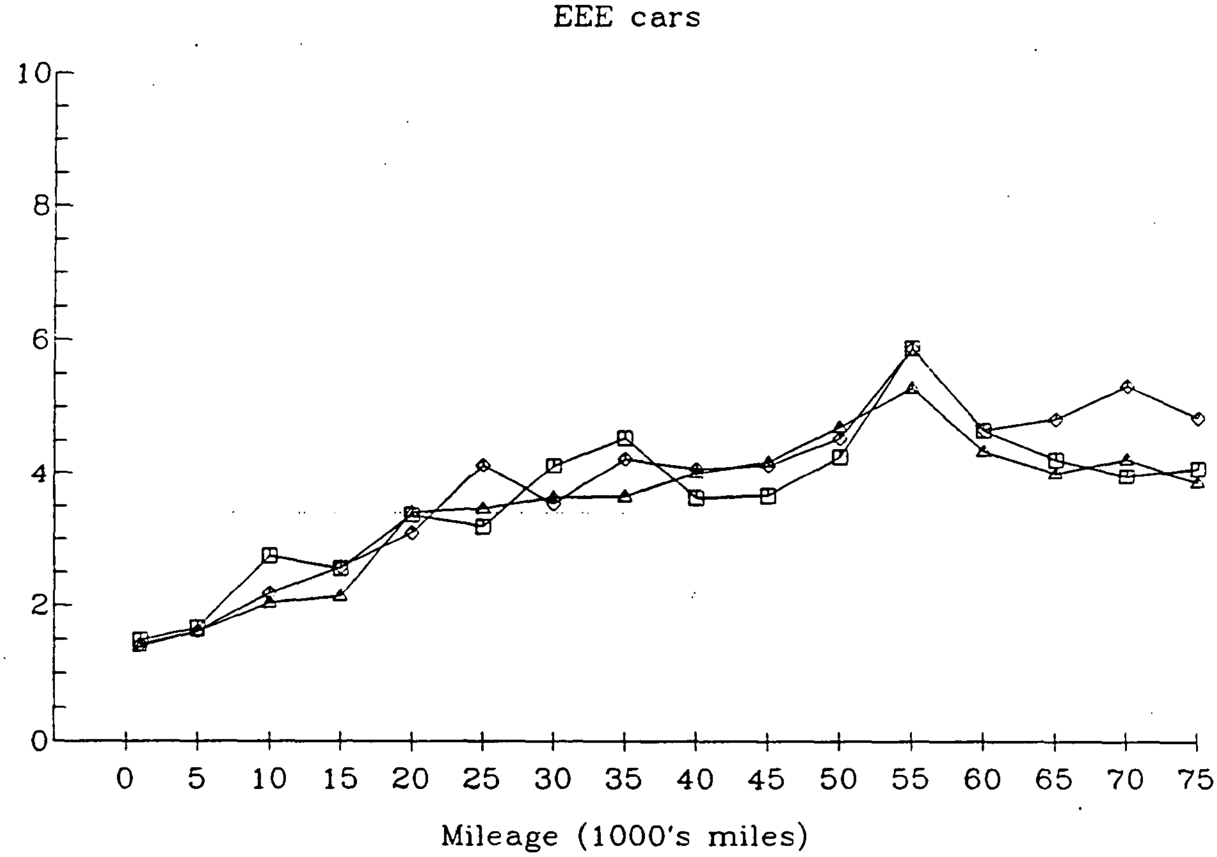
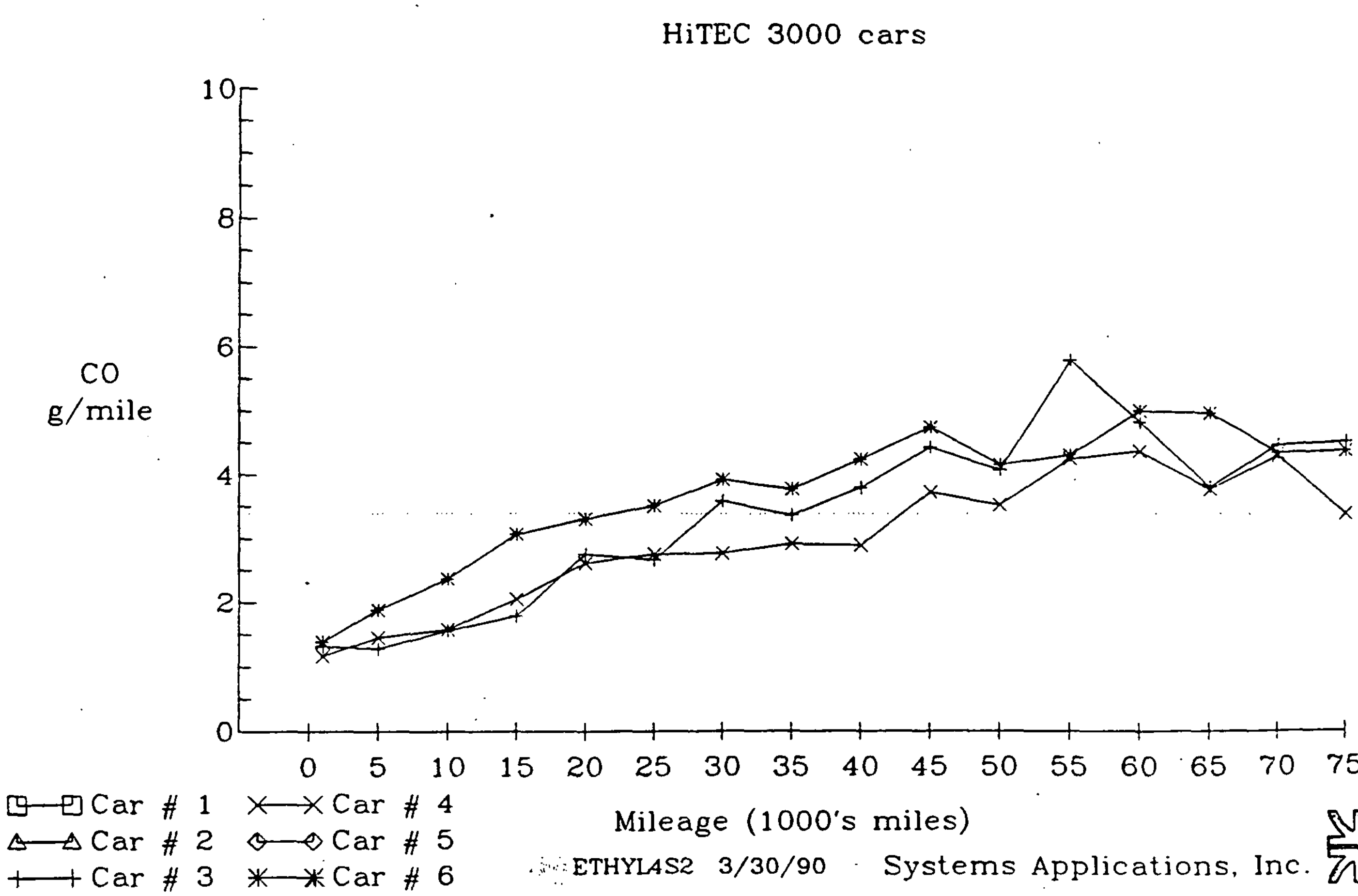
Average Tailpipe Carbon Monoxide Emissions for Model Group H





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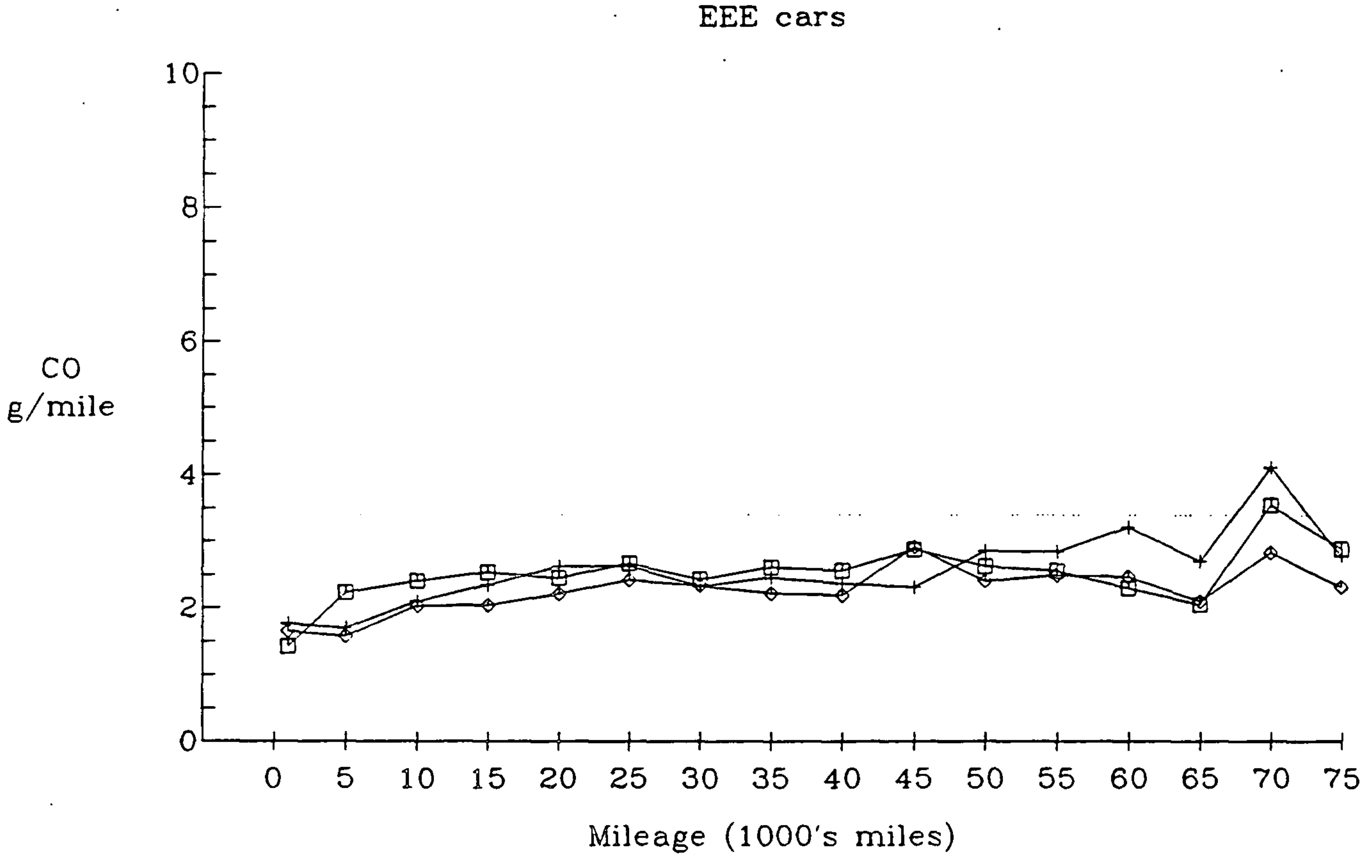
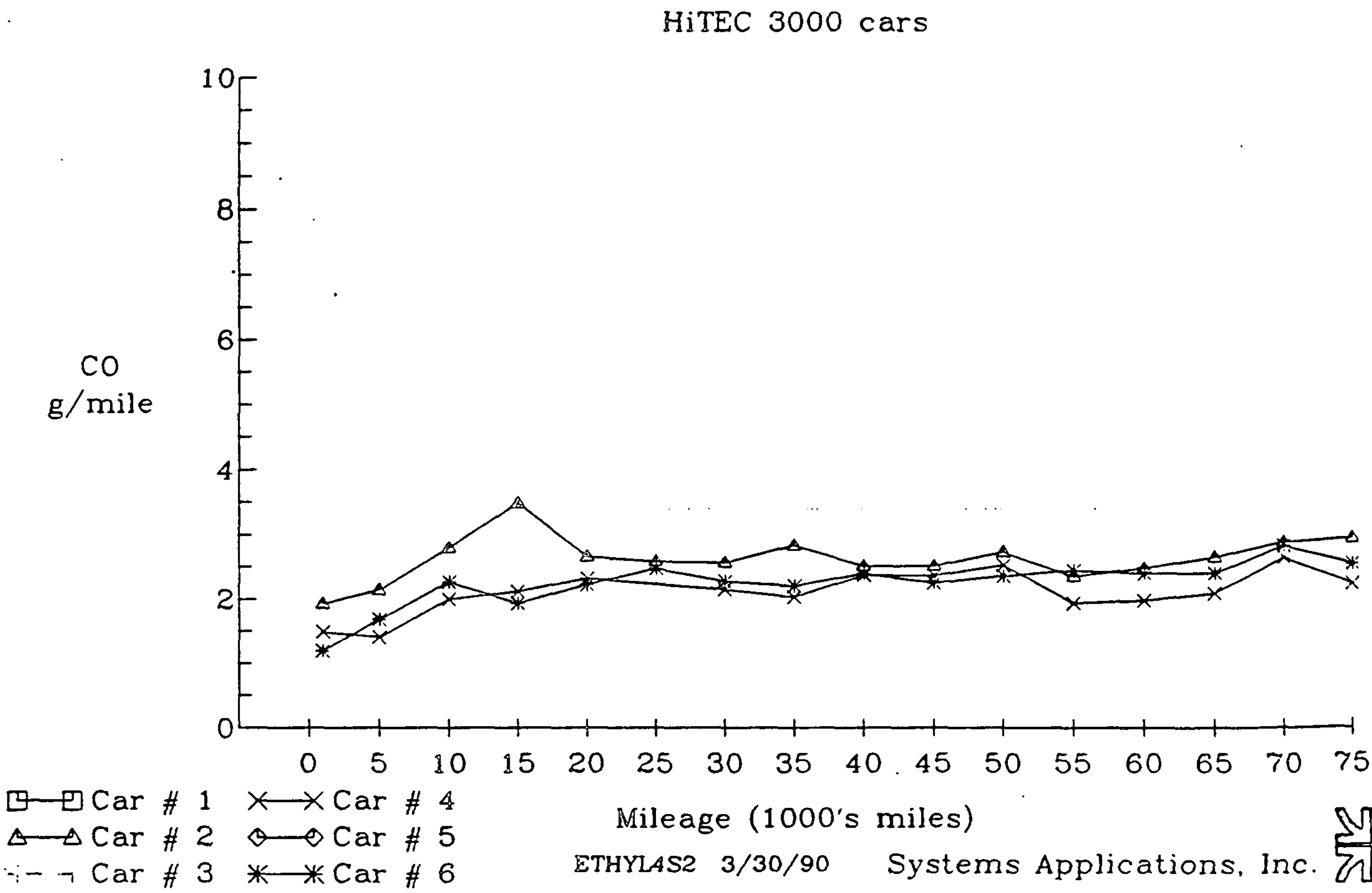
Average Tailpipe Carbon Monoxide Emissions
for Model Group I





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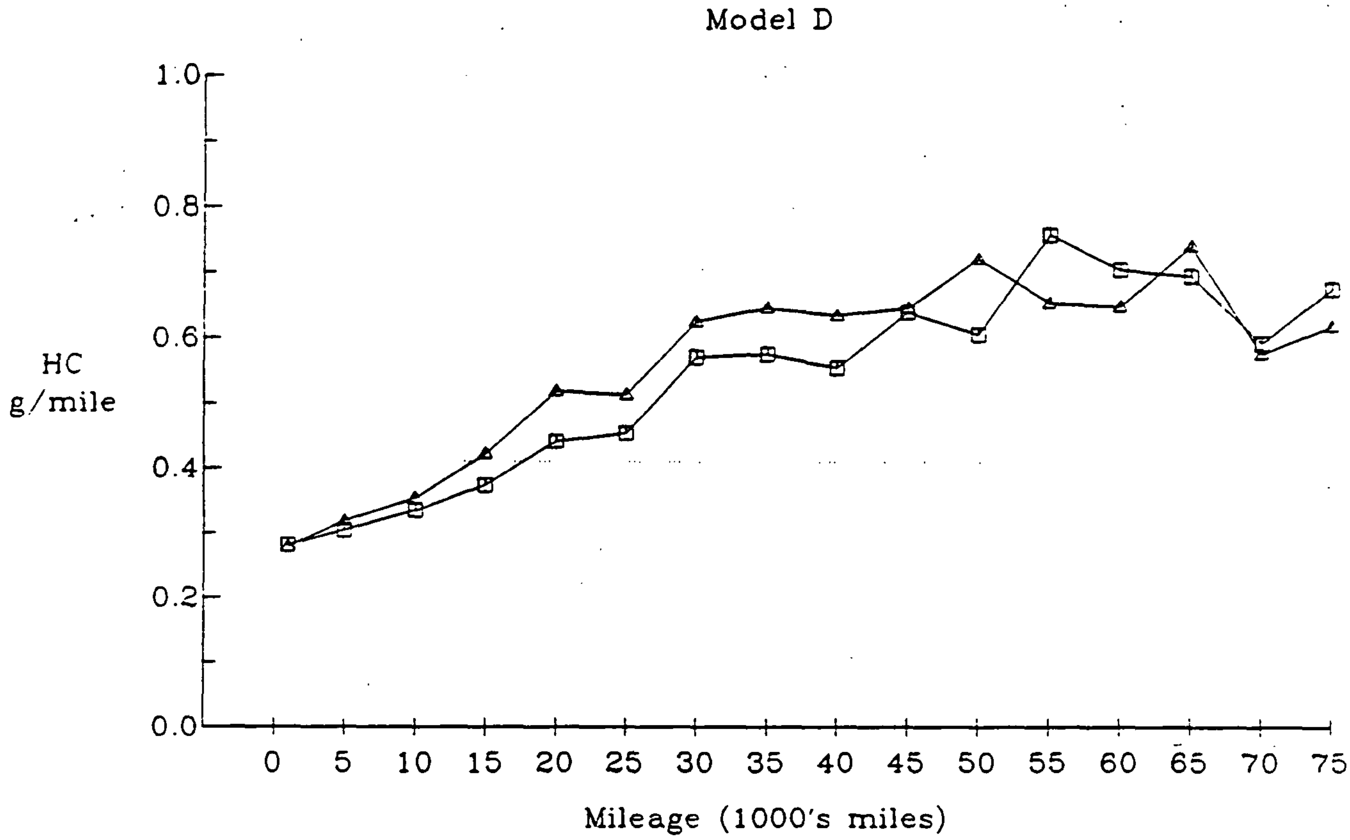
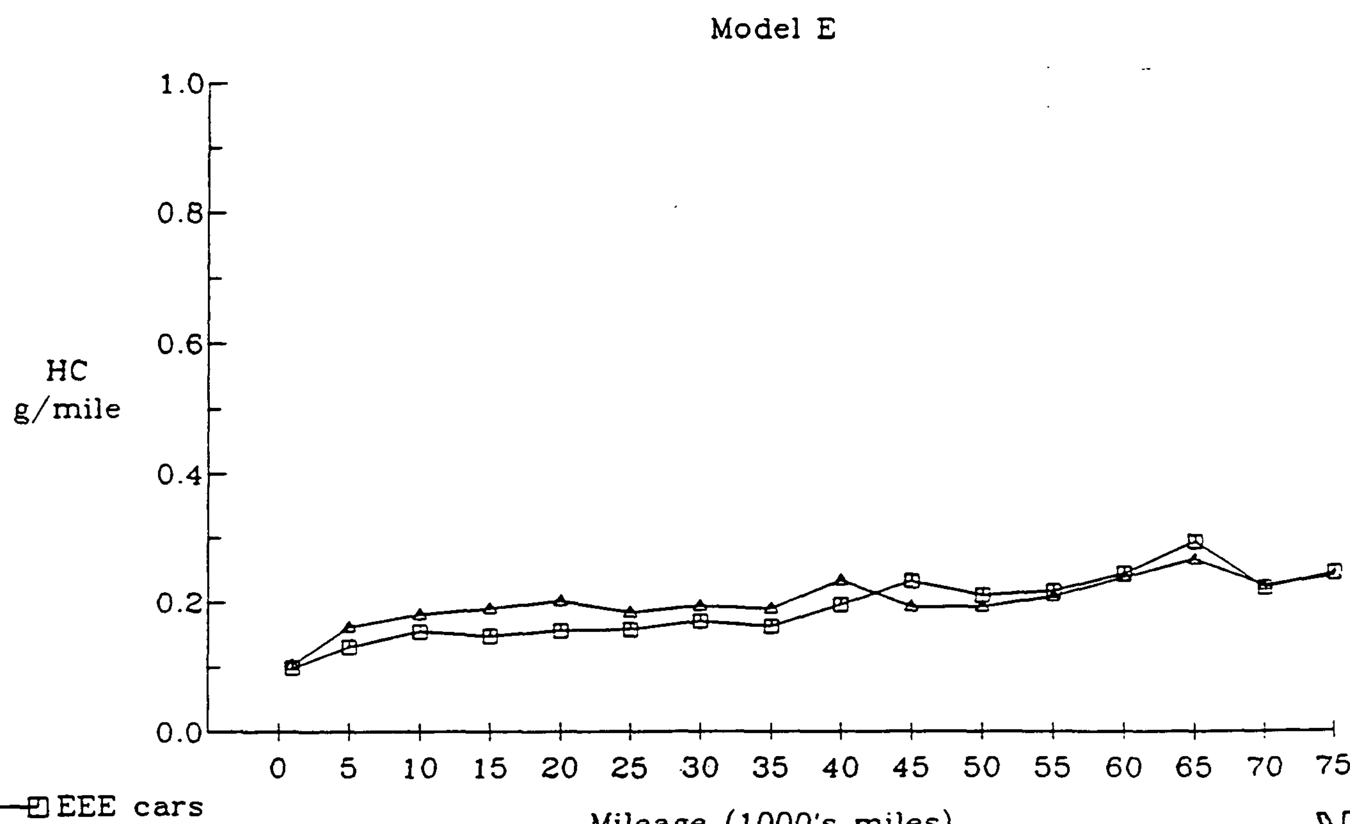
Average Tailpipe Hydrocarbon Emissions





□—□ EEE cars
△—△ HiTEC 3000 cars

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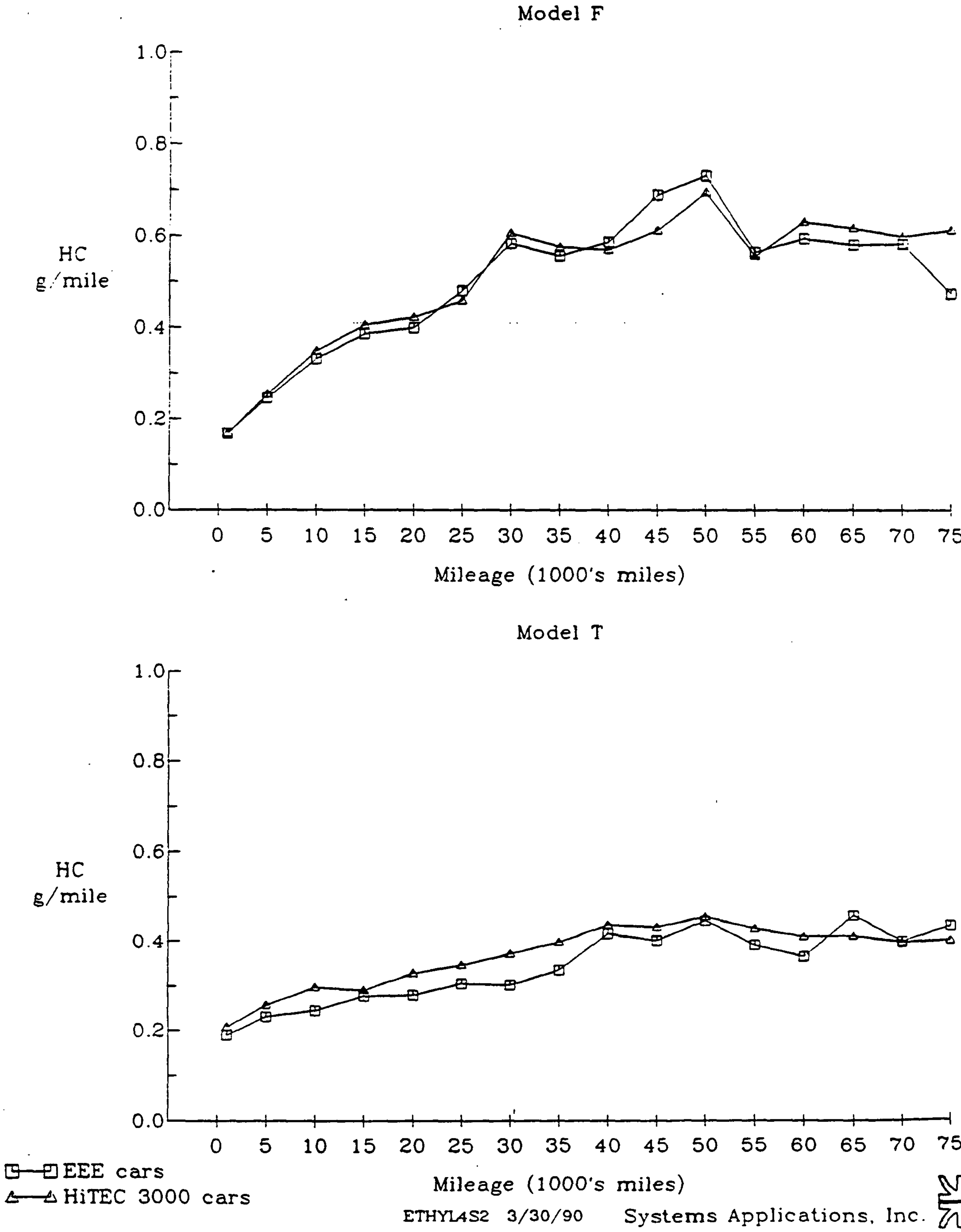
Average Tailpipe Hydrocarbon Emissions



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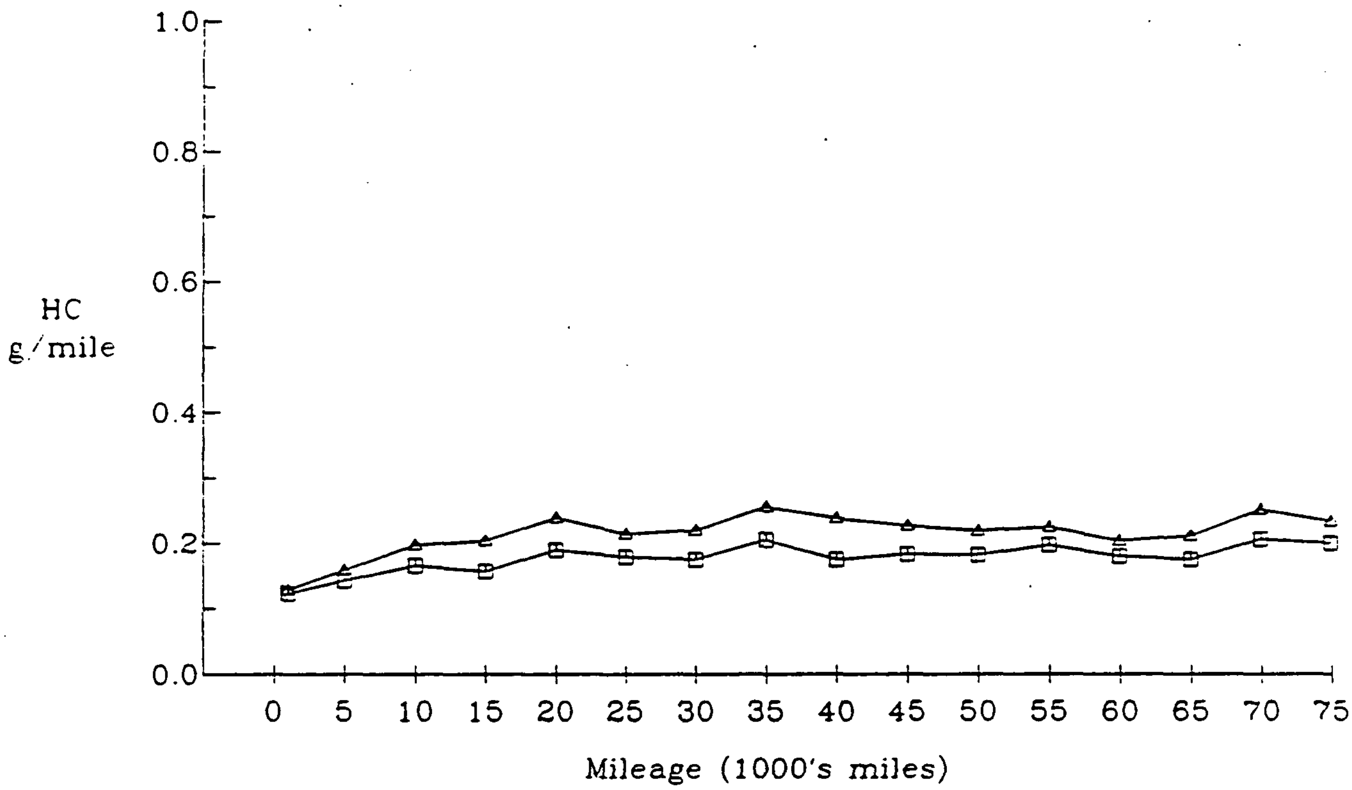
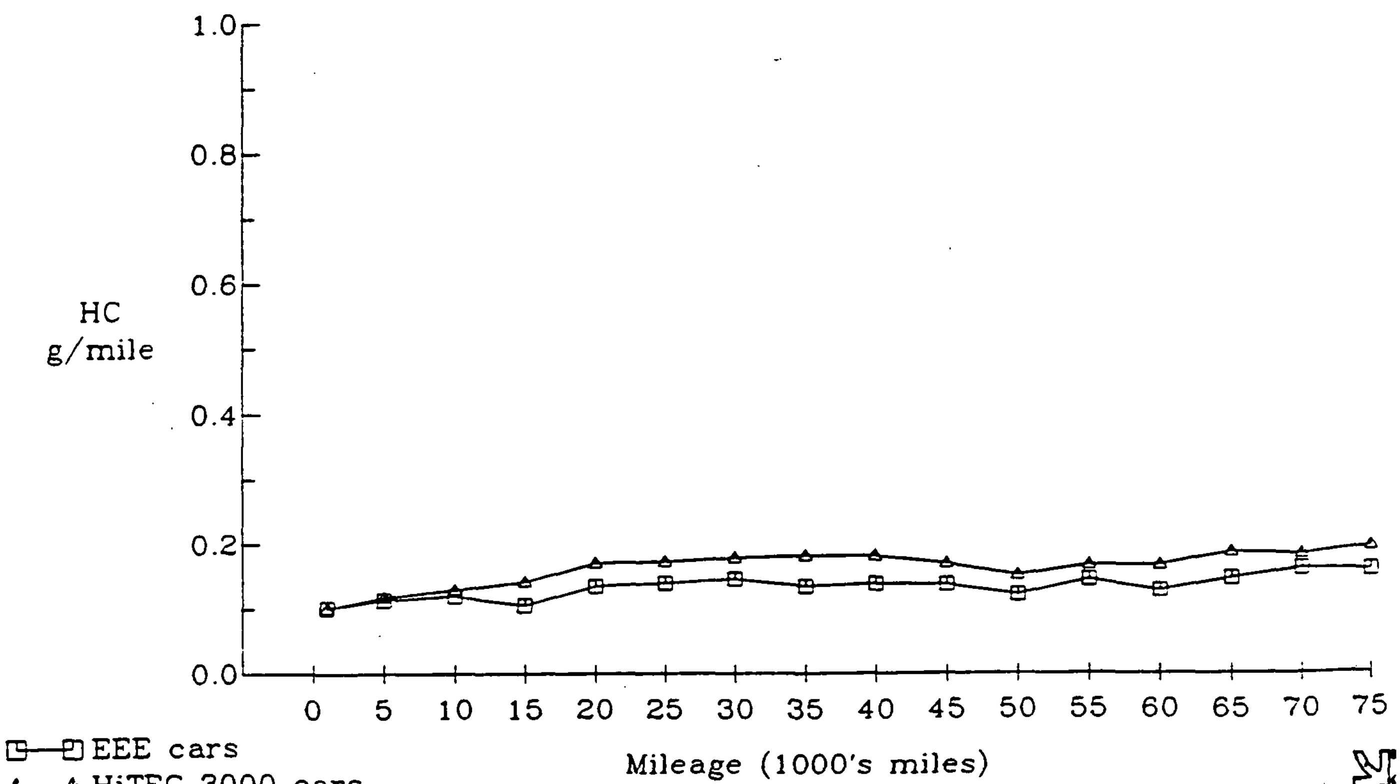
Average Tailpipe Hydrocarbon Emissions

Model C



Model G



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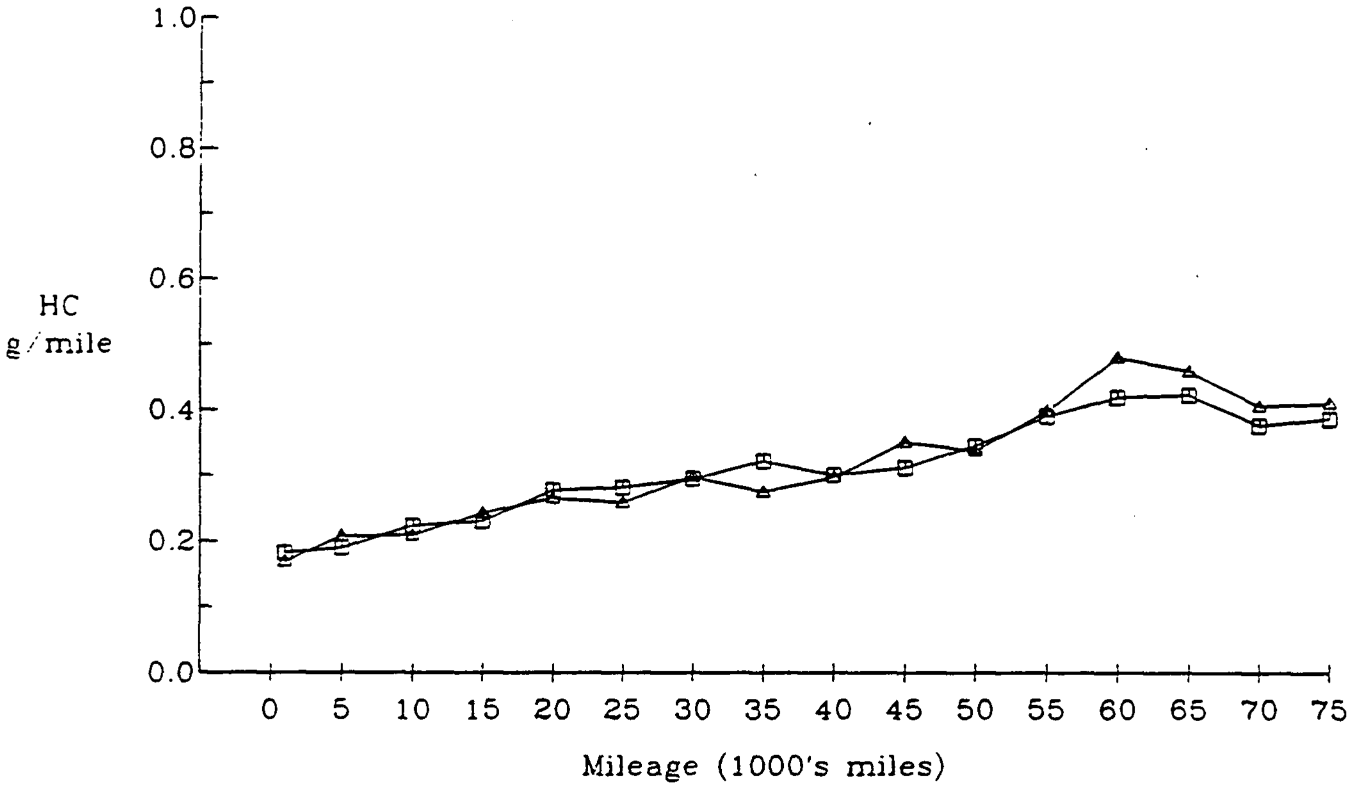
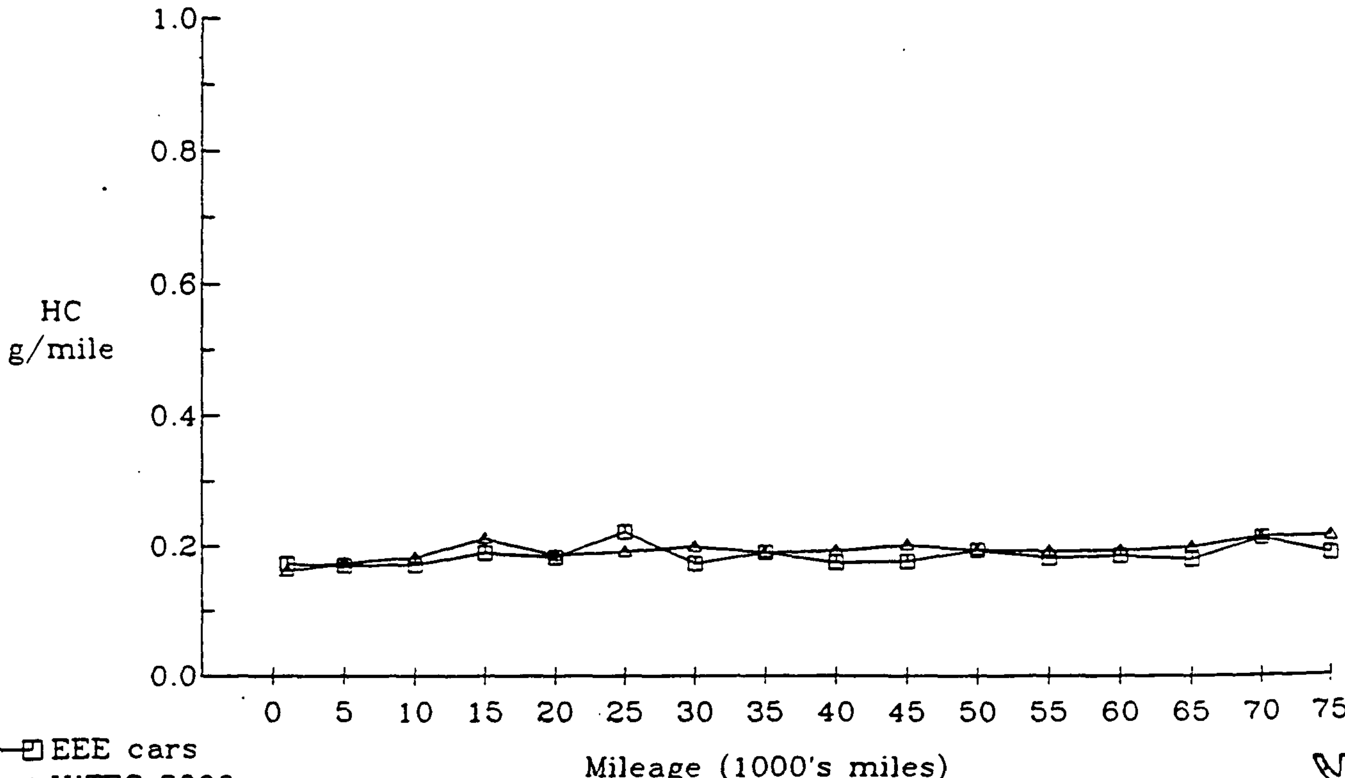
Average Tailpipe Hydrocarbon Emissions

Model H



Model I



EEE cars
HiTEC 3000 cars

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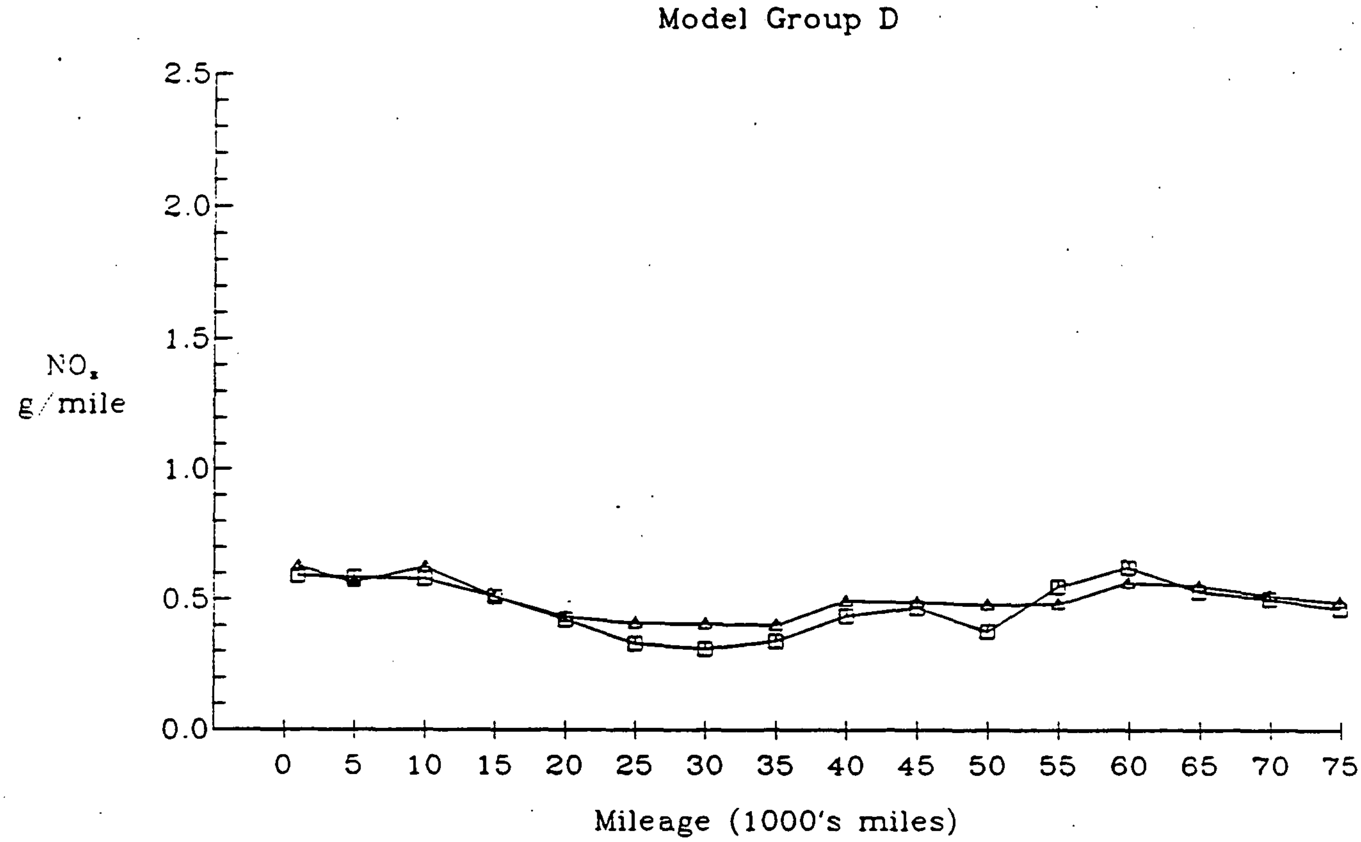
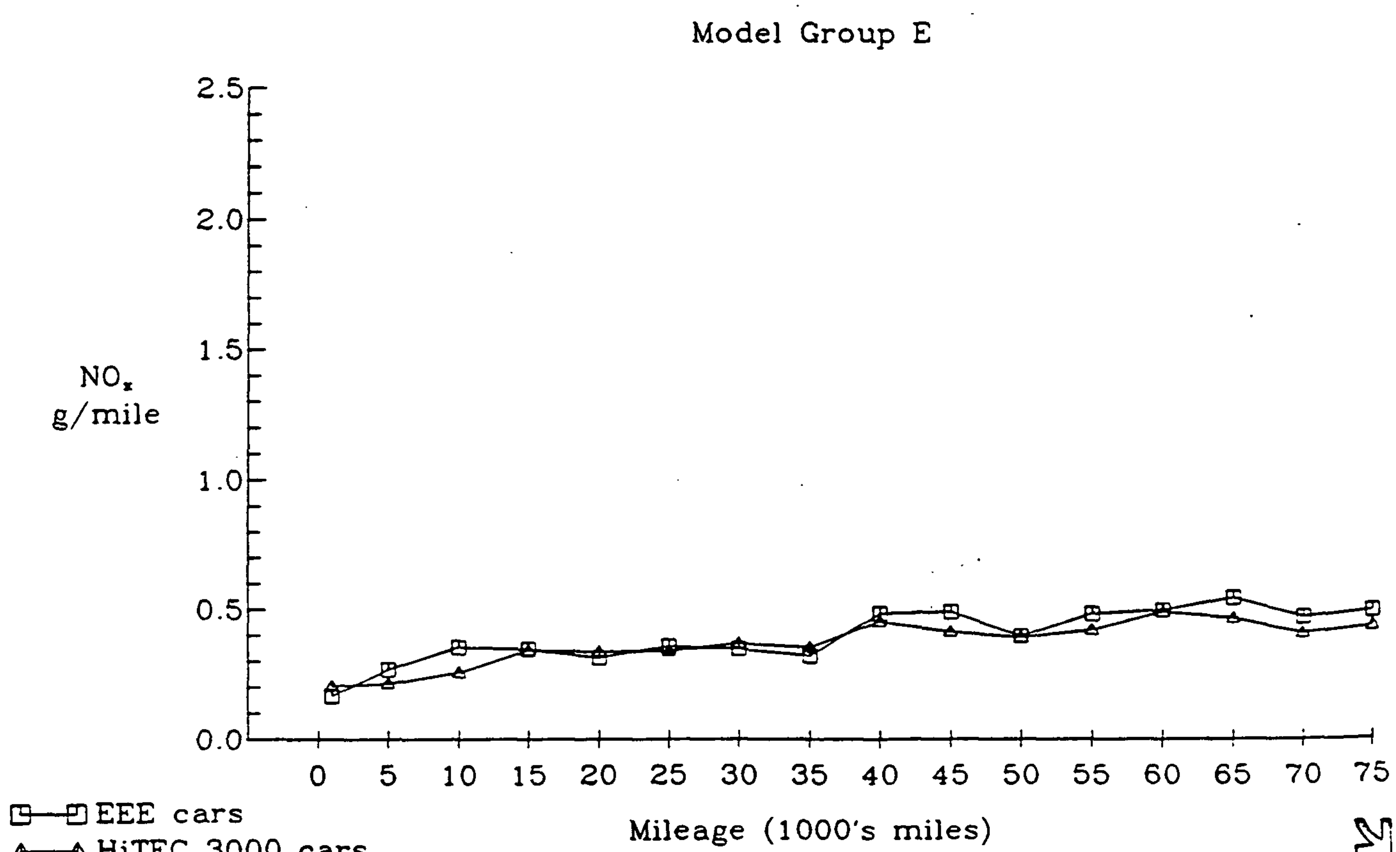
Average Tailpipe Nitrogen Oxides Emissions





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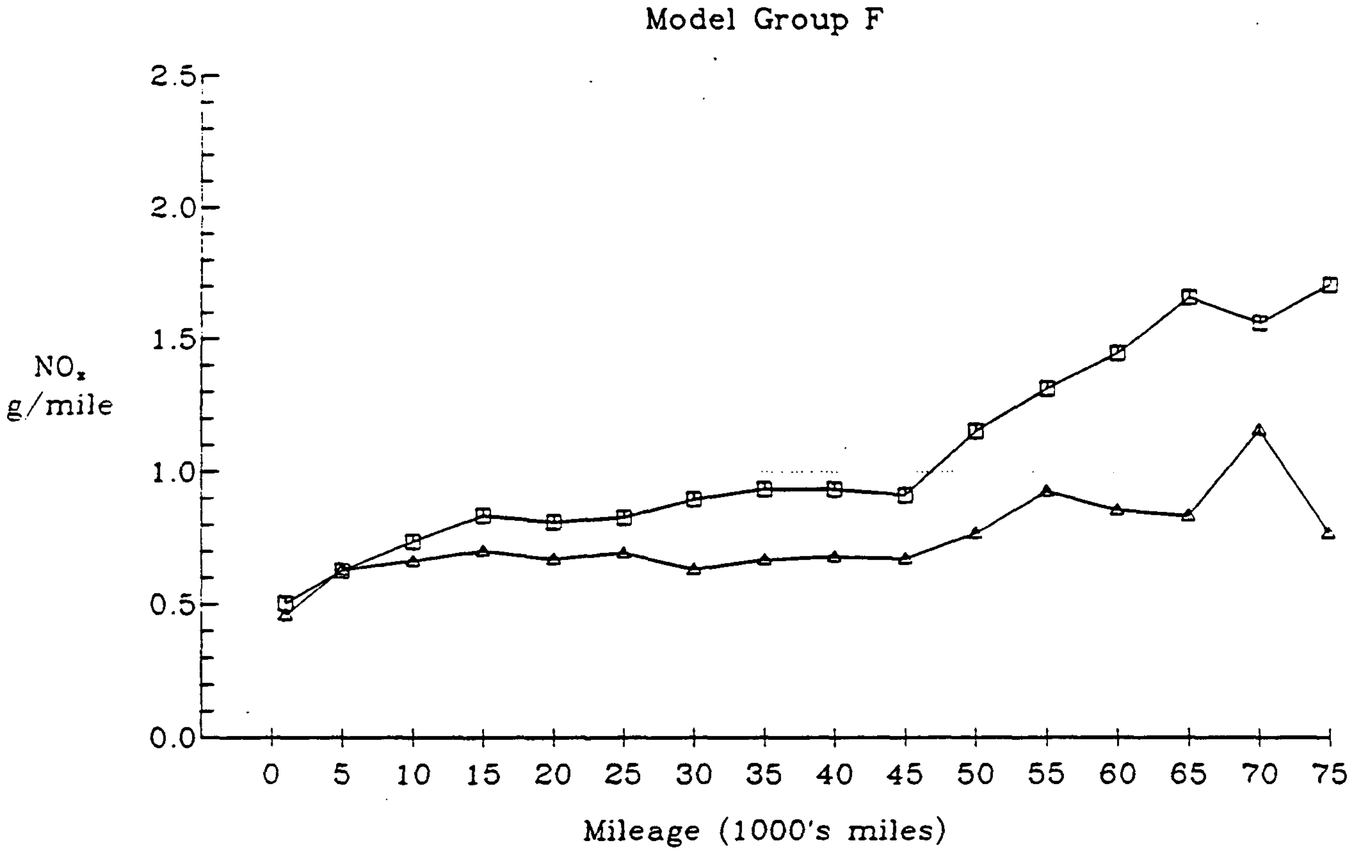
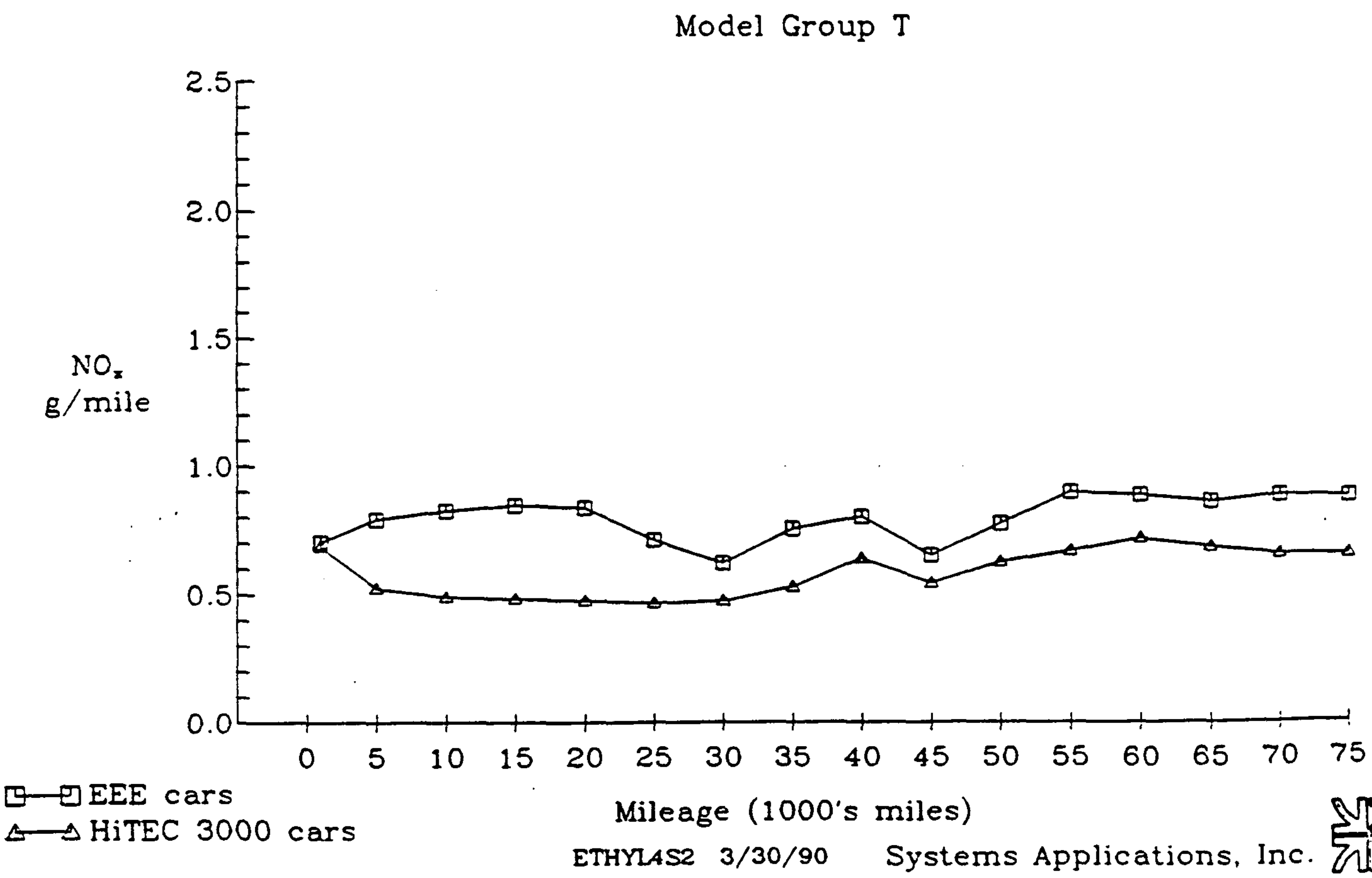
Average Tailpipe Nitrogen Oxides Emissions





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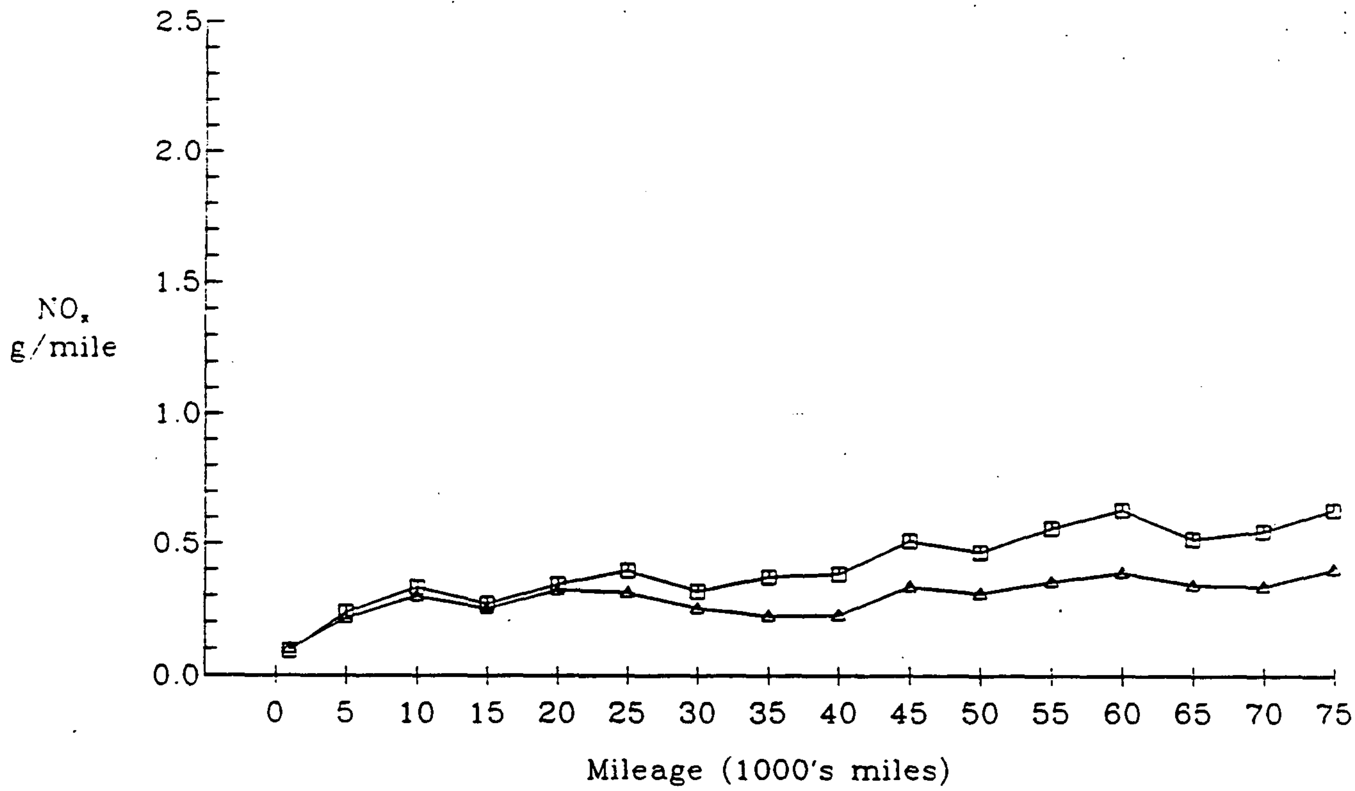
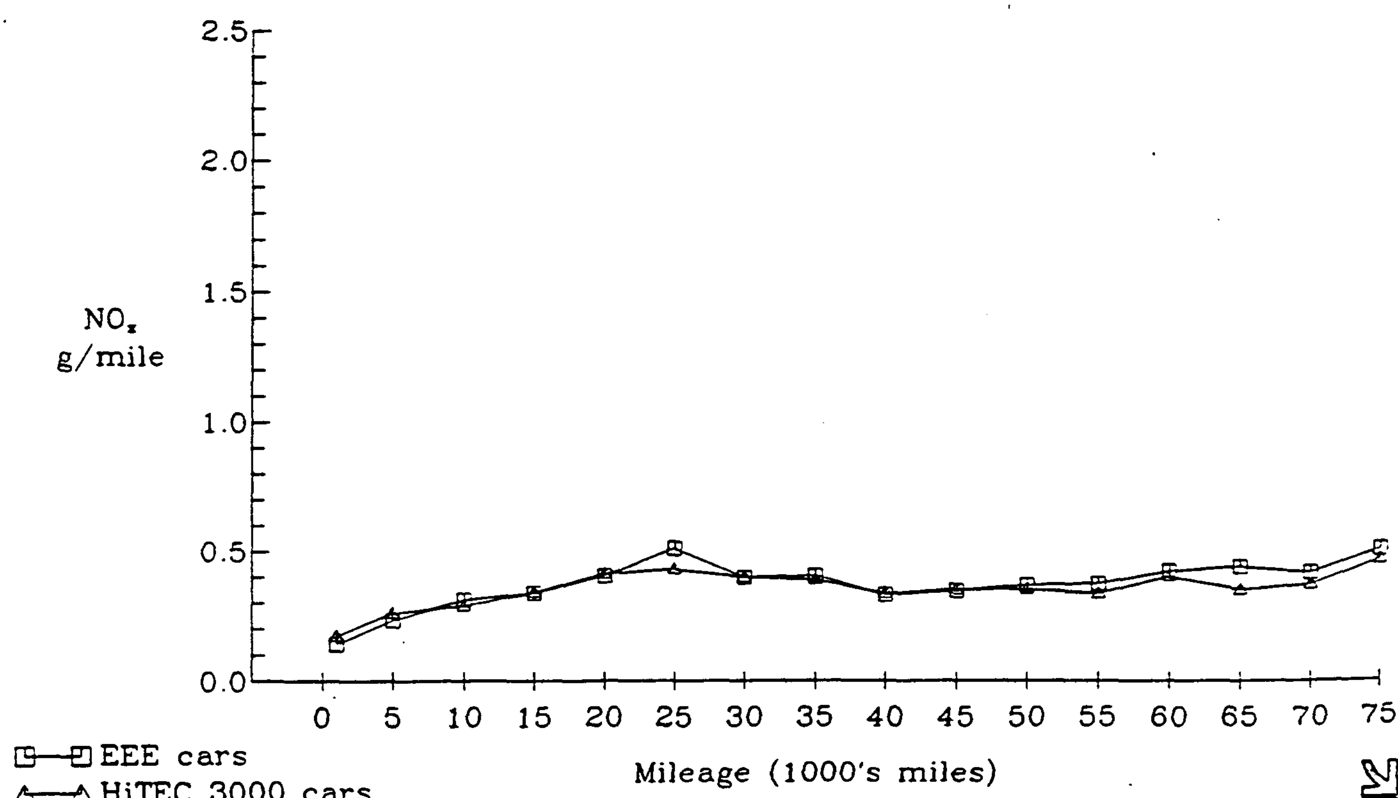
Average Tailpipe Nitrogen Oxides Emissions

Model Group C

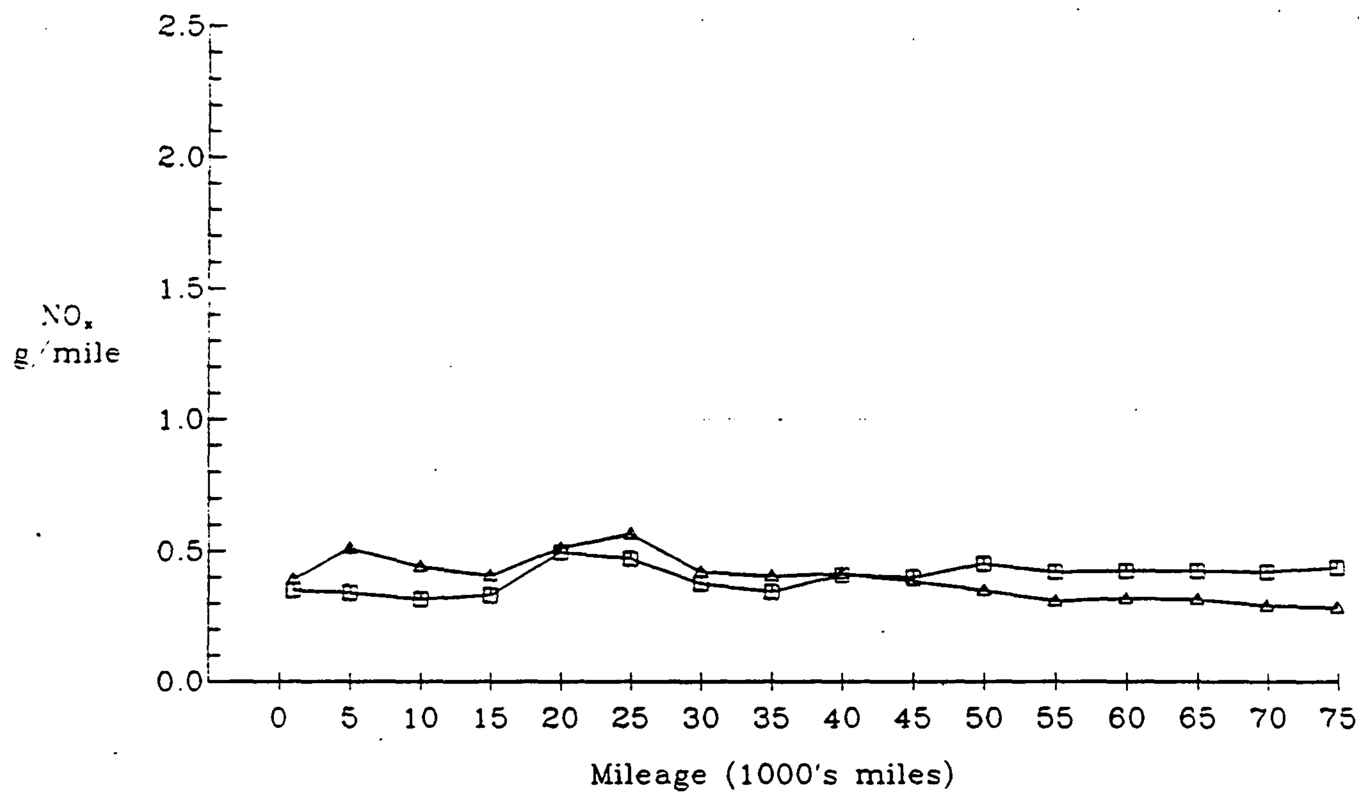


Model Group G

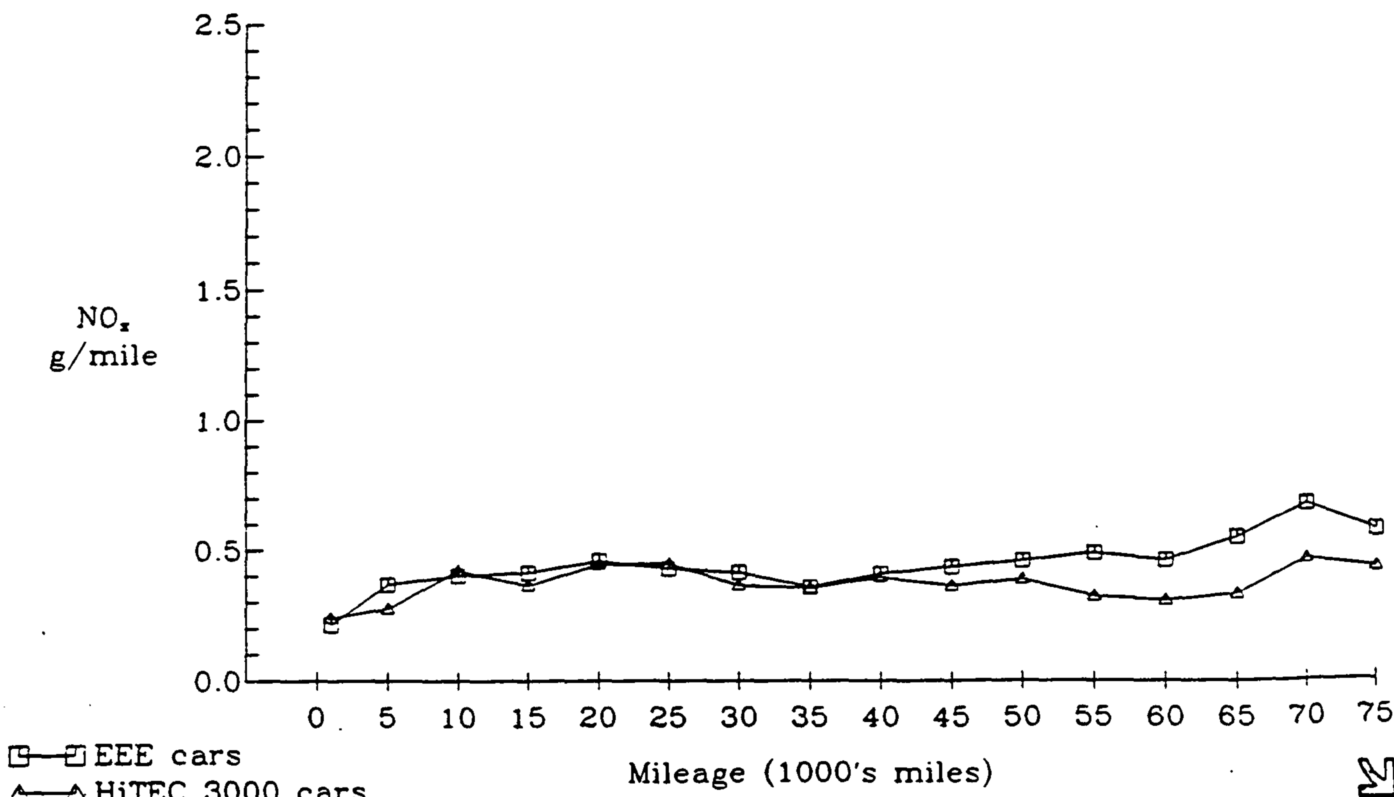


Average Tailpipe Nitrogen Oxides Emissions

Model Group H



Model Group I



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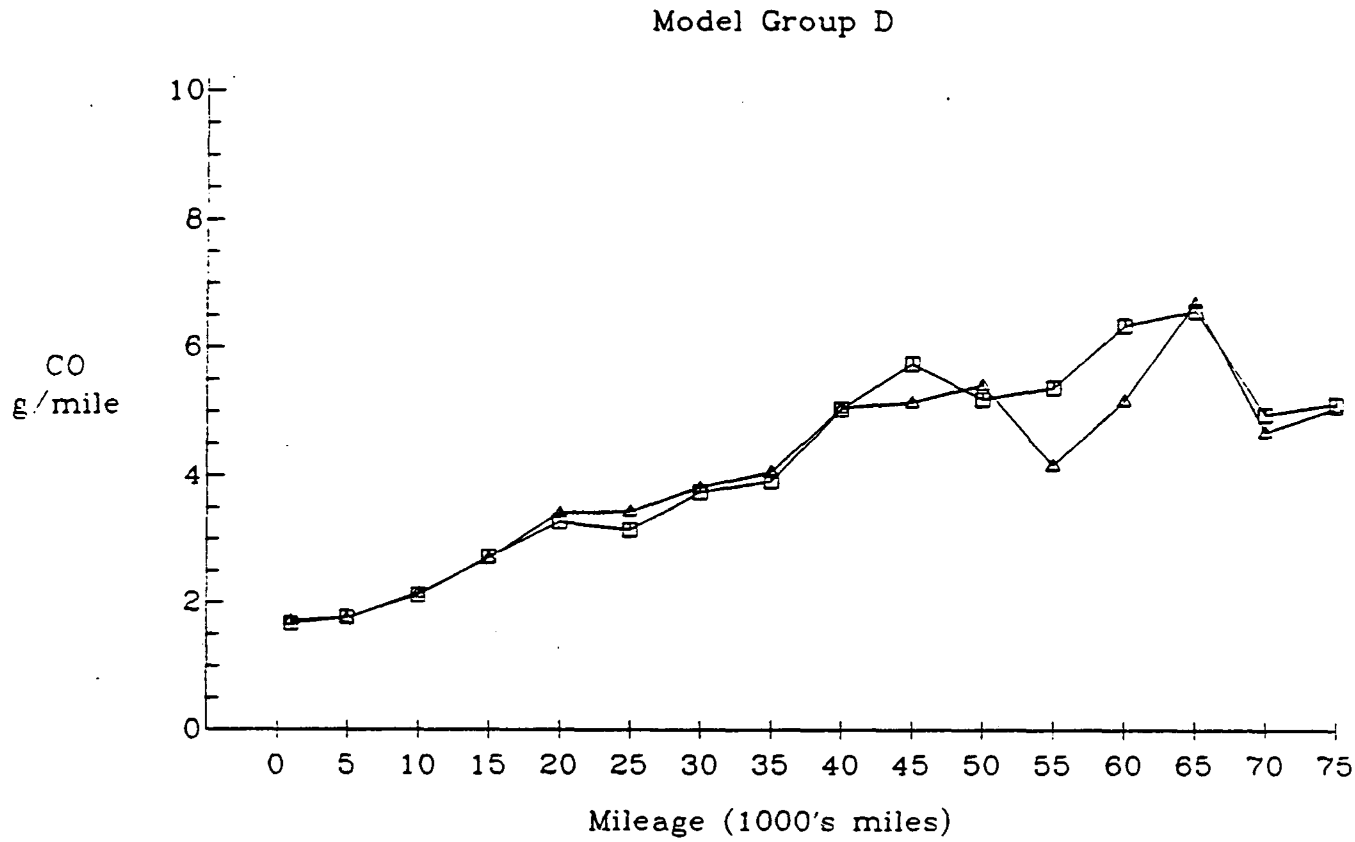
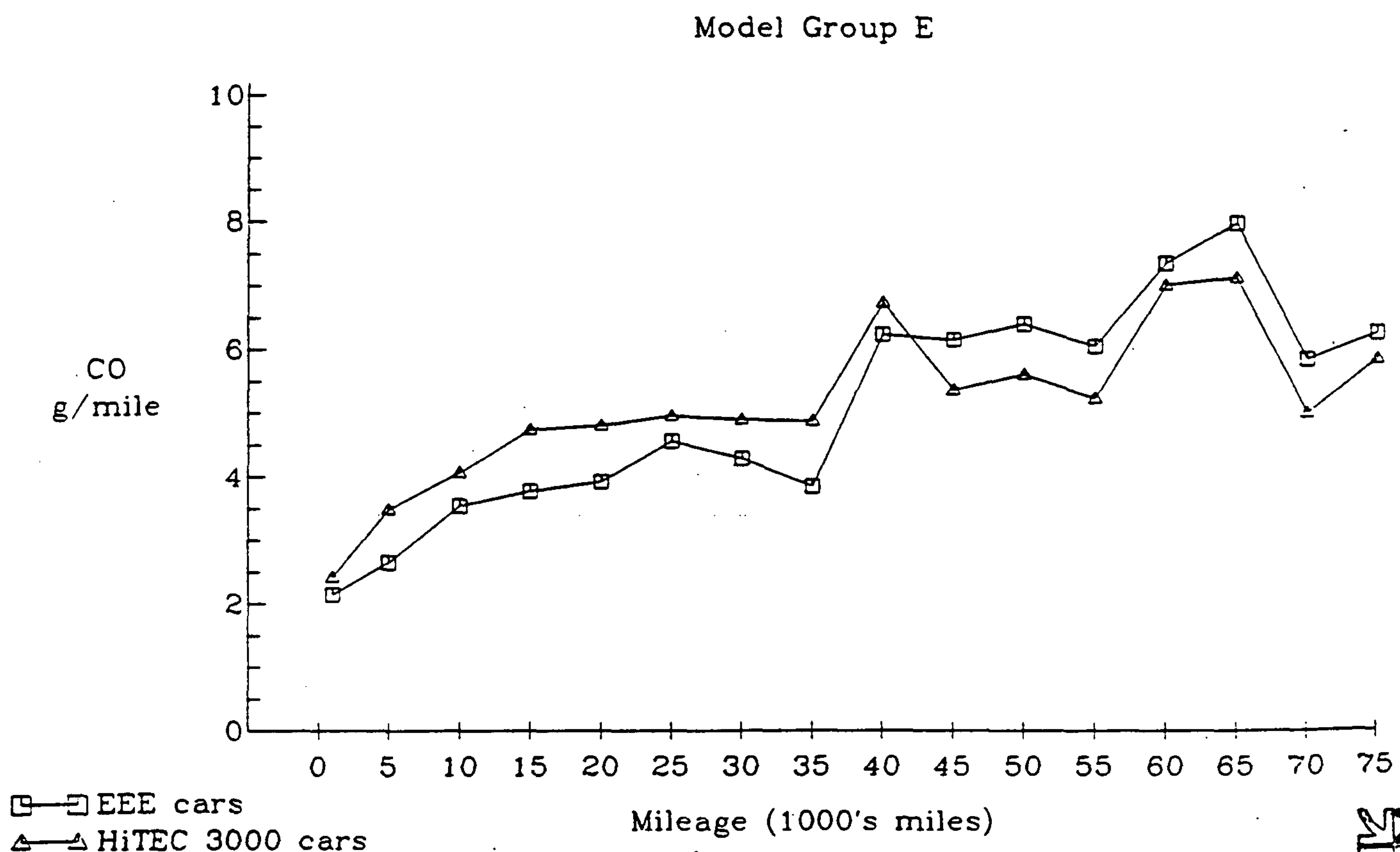
Average Tailpipe Carbon Monoxide Emissions





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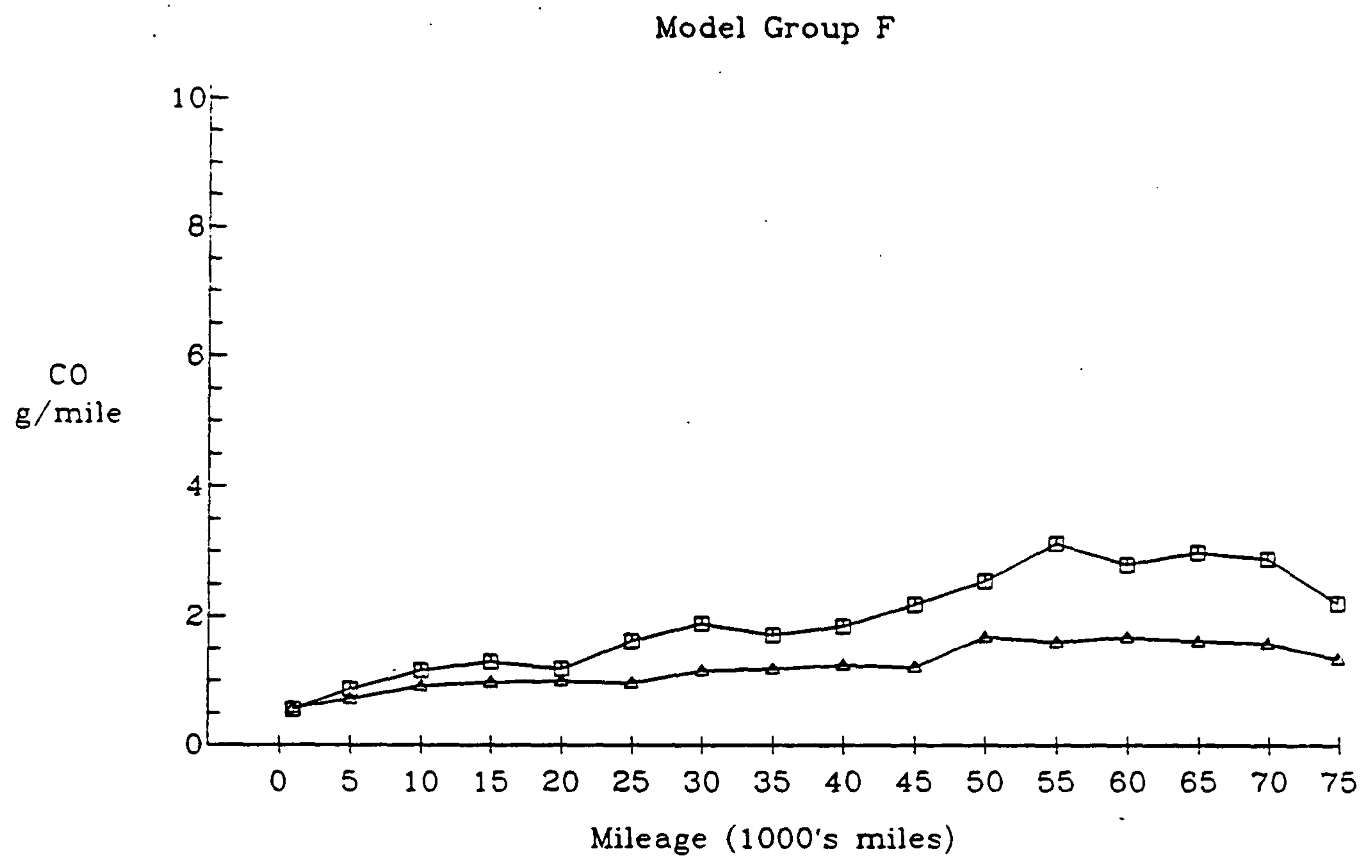
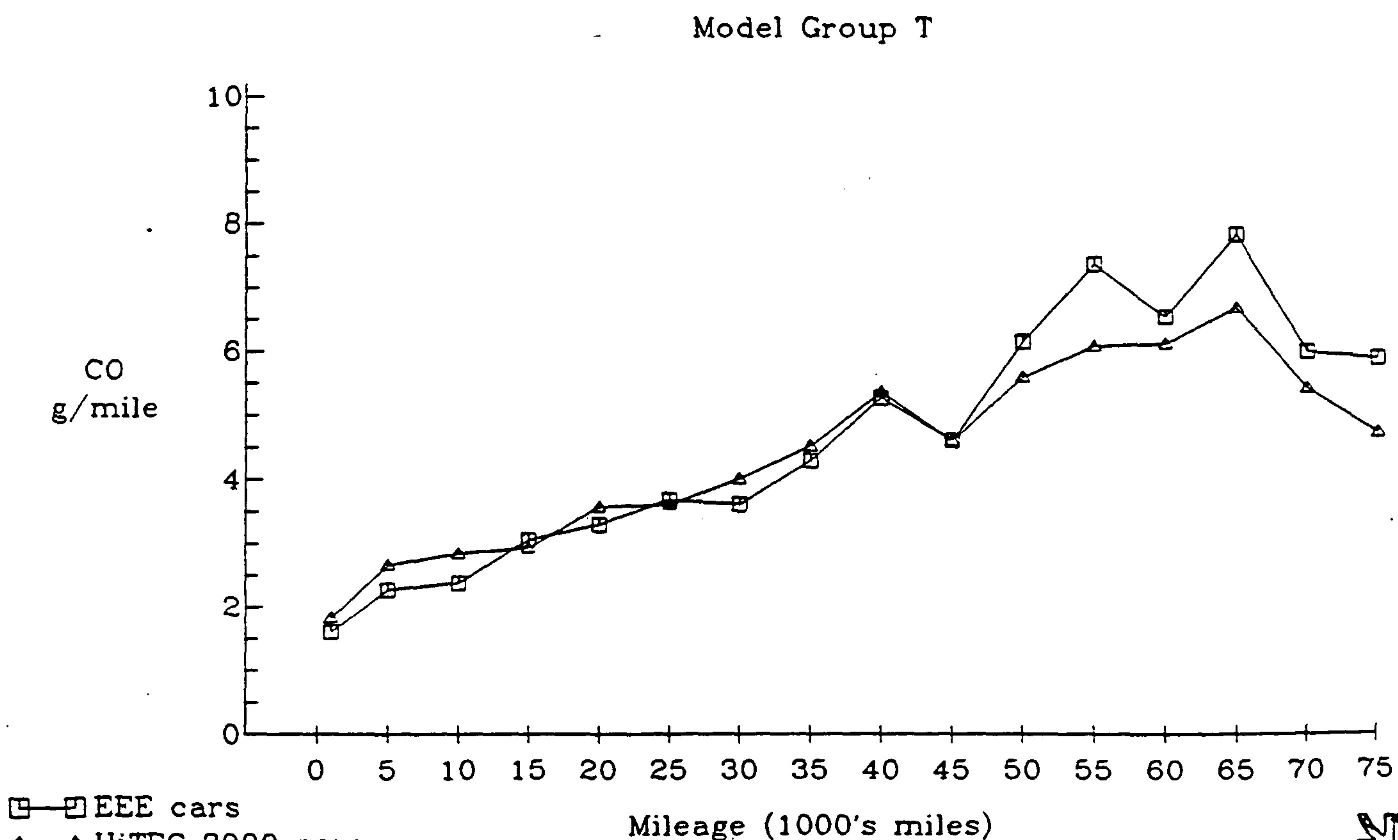
Average Tailpipe Carbon Monoxide Emissions





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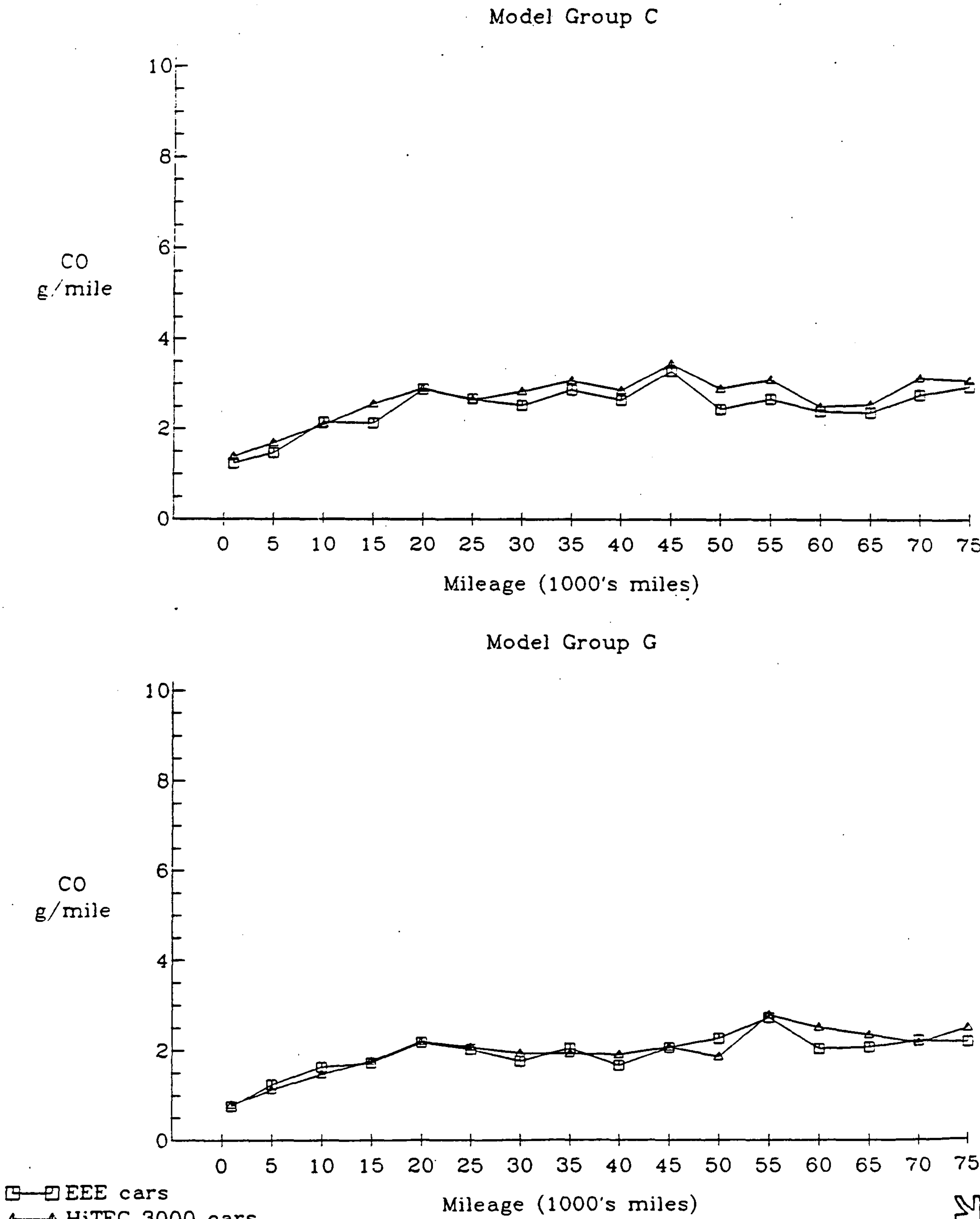
Average Tailpipe Carbon Monoxide Emissions



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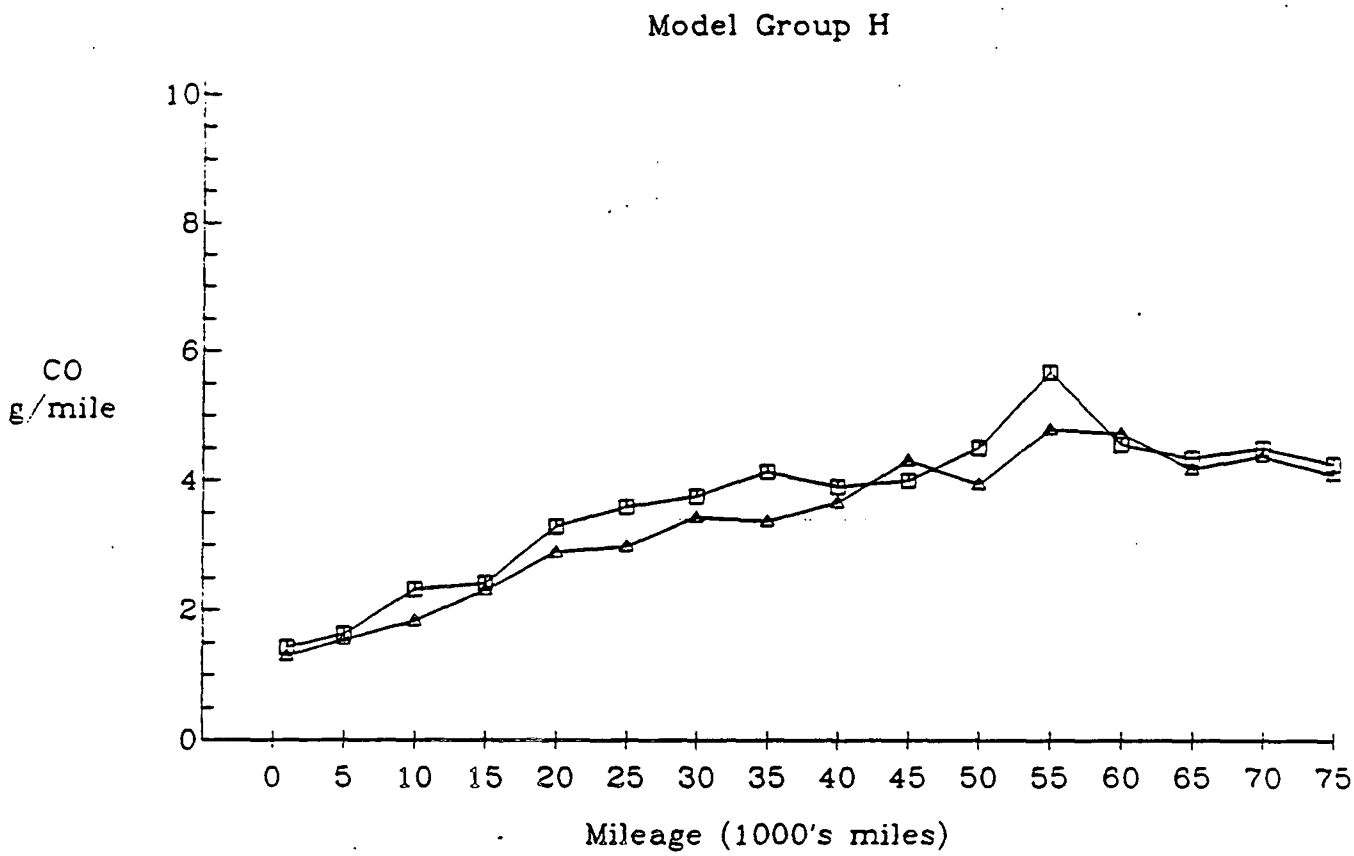
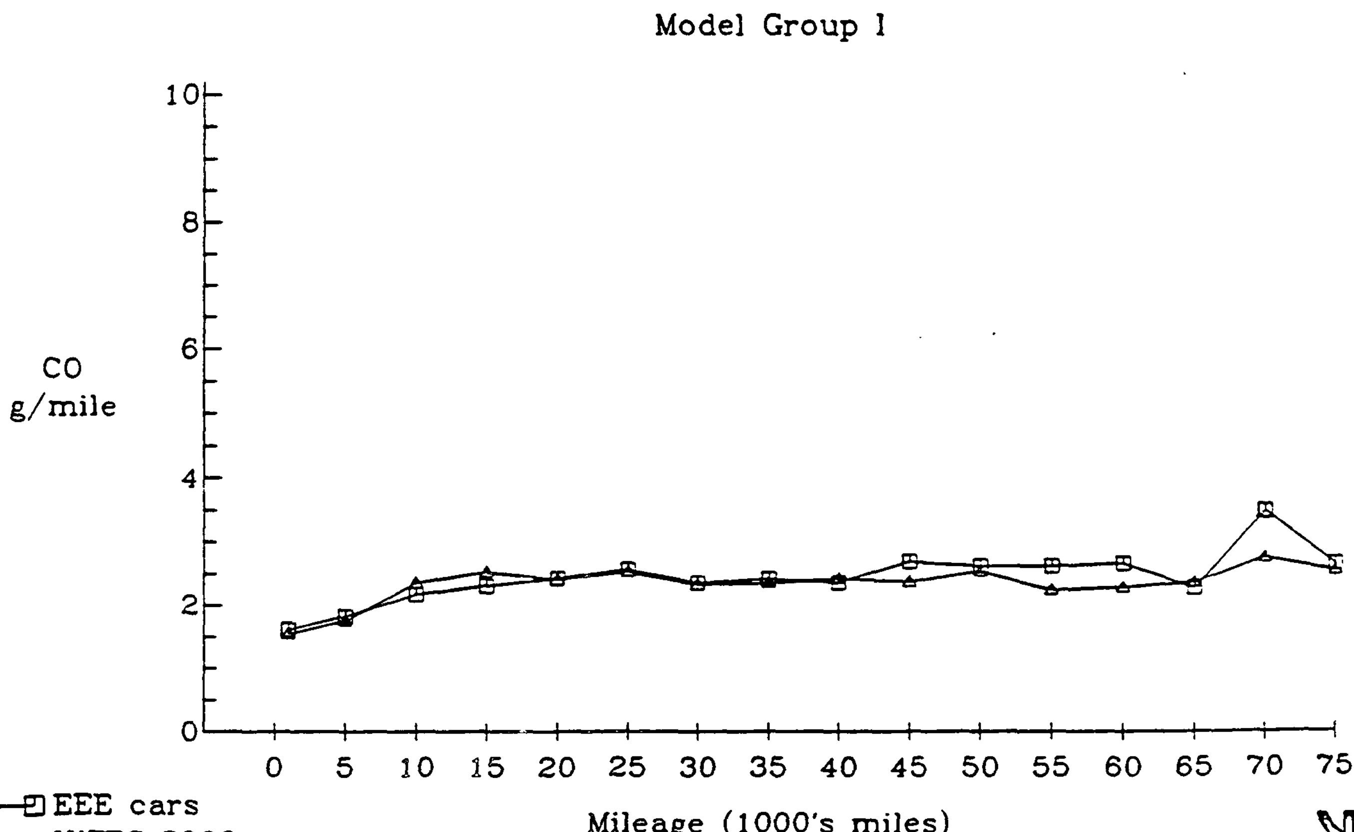
Average Tailpipe Carbon Monoxide Emissions





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